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November-December 1957

Volume VIII

Number 6

Official Publication of the **AMERICAN INSTITUTE OF INDUSTRIAL ENGINEERS, INC.**

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THE JOURNAL OF Industrial Engineering

OFFICIAL PUBLICATION OF
THE AMERICAN INSTITUTE OF INDUSTRIAL ENGINEERS, INC.

Published Bi-monthly • **AIIE Headquarters and Publication Offices, 145 North High Street, Columbus 15, Ohio** • ***Editorial Office*—A. French Building, 225 North Avenue, N.W., Atlanta 10, Georgia**

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Subscription Prices: $6, one year; $10, two years; single issues, $1.50.

All Manuscripts for review should be submitted with drawings suitable for reproduction to the Editor-in-Chief, Journal of Industrial Engineering, A. French Building, 225 North Avenue, N.W., Atlanta 10, Georgia.

Advertising Rates available from the Advertising Manager or any Editorial Board member. Send copy and cuts to the Advertising Manager, A. French Building, 225 North Avenue, N.W., Atlanta 10, Georgia.

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▶ All issues of the *Journal of Industrial Engineering* through 1956 are now available on microfilm to subscribers through University Microfilms, 313 N. First Street, Ann Arbor, Michigan.

Printed at Waverly Press Inc., Balto., Md.

The Additivity of Universal Standard Data Elements, II

By Elwood S. Buffa[1]

Associate Professor of Production Management, University of California, Los Angeles

This paper is a report of laboratory research which was performed to gain further insight into the basic additivity of universal standard data elements. It is related to a previous paper published by the author which examined the available literature on this subject, proposed a hypothesis, and an experimental design for the testing of that hypothesis (8). The experiments proposed have been carried out and the results are reported here.

Hypothesis

A large number of studies have shown that element times are intercorrelated, or that element times interact (1, 2, 3, 4, 5, 6, 7, 11, 14, 15, 16, 17, 18, 19, 20). The meaning of this is that element times are dependent not only on major variables, such as distance, class of fit, etc., but also on the other elements in the cycle and the sequence of these elements. Some writers have inferred from this that standard data elements were not additive and that, therefore, the standard data concept was invalid and not a useful tool. Another meaning of additivity is that $E(T) = E(t_1) + E(t_2) + E(t_3) \cdots E(t_n)$, where T is the cycle time to be predicted and the t are standard element times. This merely says that the sum of the expected values of the element times equals the expected cycle time. It is well known in statistics that, if we have a set of random variables x, y and z connected by a joint density function $f(x, y, z)$, then the expected value of their sum is equal to the sum of their separate expected values, thus $E(x + y + z) = E(x) + E(y) + E(z)$ (10). This is true regardless of interaction between the variables. Applying this to standard data it should be true that mean values of cycle times can be predicted from a knowledge of expected values of individual elements. The mean cycle time predicted in this manner will, of course, have a variance, part of which is accounted for by the element interaction or intercorrelation. If the degree of correlation were known, a more precise estimate of the cycle time could be obtained. The question really is whether or not the variance due to correlation increases total variance to the point where estimates of mean cycle times are not precise enough for the uses to which standard data will be put. The major hypothesis of the experiments reported in this paper is that mean cycle times may be predicted from mean element times.

Methods and Procedures

Design of Experiment

Fig. 1 is a diagram of the work place which was used to test the hypothesis. The task required the subject to assemble two parts in a fixture. Part A was a pin which was $1\frac{1}{4}$ inches long and $\frac{1}{4}$ inch in diameter, chamfered at one end. Part B was a bushing, $\frac{3}{4}$ inch in diameter, $\frac{1}{2}$ inch thick, and with a concentric hole of 0.26 inch. The cycle for the right hand is given below:

1. Reach to part A
2. Grasp part A
3. Move to manual advanced button, depress button
4. Move part A to hole No. 3 in fixture
5. Position part A in hole and release
6. Reach to part B
7. Grasp part B
8. Move part B to hole No. 4 in fixture
9. Position part B in hole and release
10. Reach to part A in hole No. 3
11. Grasp part A and remove from hole No. 3
12. Move part A to part B in hole No. 4
13. Position part A in part B
14. Release part A
15. Reach to disposal button
16. Depress button

Part A was fed to the subject from a dual feeder at a rate determined by the subject for unpaced conditions and by the experimenter for paced conditions. Part A was taken from the well, a manual advance button was pressed and then part A was moved to a fixture and positioned in hole No. 3. Part B, which was a bushing, was then procured from its rack and moved to the fixture and positioned in hole No. 4. Part A was then procured from hole No. 3 and positioned in the center of part B, which was in hole No. 4. The subject then pressed the disposal button, energizing a solenoid which withdrew a slide causing parts A and B to drop into a disposal chute. The cycle described above by the list of 16 elements was called the complete cycle.

An incomplete cycle was formed by eliminating the transfer of part A from hole No. 3 to the concentric hole in part B. Thus elements No. 1 through 8 plus No. 15 and No. 16 make up an incomplete cycle. In the complete

[1] A portion of the work reported in this paper was done while the author was under contract to the Office of Naval Research, Logistics Branch, and working on the Management Sciences Research project, University of California, Los Angeles.

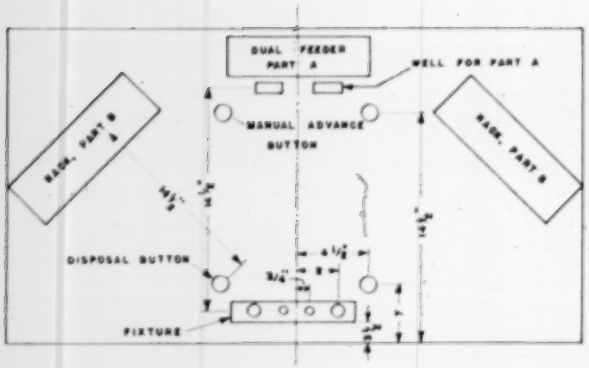

FIG. 1

cycle elements No. 9 through 14 were measured separately so that all cycle times quoted in this study are for the incomplete cycle actually measured for half of the trials, and forecast for the other half of the trials by subtracting the time for elements No. 9 through 14 from the cycle times measured. The contrast of cycle times measured and cycle times forecast for the incomplete cycle forms the basis for testing the major hypothesis, and is labeled as a variable, Method of Estimation:

Four variables were manipulated in the experiment. These were:

A. Pace (three levels; two paced, one unpaced)
B. Method of Estimation (two levels)
C. Discrimination (two levels)
D. Hands Used (right hand vs. both hands)

These variables were combined in a factorial experiment. The variable of Pace was introduced into the task by means of the dual feeder. The dual feeder was actuated by a rotary solenoid, which advanced one part into the well just in front of the feeder. The feeder was controlled by a synchronous motor driven cam under paced conditions. The cam closed a normally open micro-switch which energized the rotary solenoid. Another micro-switch, timed from the same cam, energized a linear solenoid which actuated a slide in the bottom of the well causing part A to drop into a box below the table. A part would then be advanced into the well by the feeder and remain available to the subject until the linear solenoid was energized at which time it dropped from view, and another part was advanced into the well. Different levels of pacing were selected by inserting cam rises. Two levels of pacing were selected. These were at the rates of 5.55 pins per minute and 11.10 pins per minute. The lower level of pacing was a relatively slow pace for the task and hesitations were normally required by the subject. The higher level of pacing was relatively fast and required the subject to make an effort to keep up with the rate of feeding. An unpaced condition was established by switching the control of the rotary solenoid from the control motor to a micro-switch which on being depressed by the subject caused a rotary solenoid to be energized and a part to be advanced. The manual cycle for both the paced and unpaced conditions remained the same.

The variable Discrimination was introduced by painting a yellow band around part B. The two levels of Discrimination were, no discrimination required at the lower level, and discrimination required at the upper level. At the upper level of Discrimination the subject was directed to select only those parts with yellow bands around them from the racks.

The variable, Hands Used (right hand vs. both hands) was a contrast between a lower level where only the right hand was used and an upper level where both hands were used simultaneously to make duplicate assemblies. This variable was introduced as a control variable.

Instrumentation

Time measurements were made for cycle times and for four elements or groups of elements. Measurements were accumulated for twenty cycles in all instances so that each measurement represented an average. The total cycle times were accumulated on a precision clock. In order to measure the shorter internal elements, a combination of three Eccles-Jordan electronic switches and counters were required.[2] The electronic switches and counters had a basic accuracy of 1/10,000 of a second and were actuated by the subject as he touched various fixed points in the manual cycle. There were no direct electrical connections to the subject and the electrical contacts made by the subject were sub-threshold. All instrumentation was put into operation by turning a multiple rotary switch. This was done by the experimenter and was sychronized with the depressing of the disposal button. All time measurements were made for the right hand.

Experimental Procedure

Sixteen male university students with preferred right-handedness served as subjects. The measurements were planned to reflect averages over twenty cycles in all instances. Each measurement then had relative stability in terms of cycle-to-cycle variation. Each subject was sampled twice for each treatment combination, the first sample of twenty cycles being taken after a standard practice period of 50 cycles. A comparison of the first sample with the second provides a measure of practice effects.

In pretests of the task used, it was noted that major changes in the tasks severely affected the subject's ability to perform the task. This was particularly true for changes from the complete cycle to the incomplete cycle and vice versa. It was the tendency of subjects to introduce extraneous elements in the incomplete cycle and to omit them

[2] The author is indebted to Christian Rand for his work in adapting the Eccles Jordan flip flop circuits to work measurement instrumentation (12, 13).

in the complete cycles. This was also true to a lesser extent for changes in the Hands Used variable. On the basis of a negative transfer demonstrated, it was decided that a departure from complete randomization of the order of presentation of treatment combinations was justified. Half of the subjects (chosen at random) were presented with a sequence complete-incomplete and the other half with the sequence incomplete-complete, on a two-day schedule. Each group was further subdivided so that half of them were presented with a right hand-both hands sequence, and the other half with the reversed schedule. Within this structure, the presentation sequence was randomized.

The table height was set at 28 inches and an adjustable chair was used to vary the relative height of the subject in relation to the table. In all instances the chair was adjusted so that the subject's elbow was about 3 inches above the table top with erect sitting posture.

Experimental Results

The factorial experiments described were performed. The measurements made were:

1. Cycle times.
2. Time for the Added Elements (these times occurred in only the complete cycle). Elements No. 9 through 14.
3. Time for the Grasp plus Transport Loaded of part B (bushing). Elements No. 7 and 8.
4. Time for the Release of part A (pin) after its insertion in the bushing hole. (These times occurred in only the complete cycle). Element 14.
5. Time for the Position plus Release of part B (bushing) in the fixture. (These times were measured in only the incomplete cycle). Element No. 9.

The specific results and their implications for each of these measurements will be discussed in the above order. This will be followed by a general discussion of the implications of the experiment as a whole.

Preliminary analysis of the raw data for the five measurements by use of Bartlett's test for homogeneity of variances indicated a rejection of homogeneity as a hypothesis for all measurements except No. 4, (time for the release of part A). This is not a surprising result since the very nature of a time scale is likely to produce a skewed distribution of observations since the scale is bounded by zero at one end and by infinity at the other. The practical result of non-homogeneity is that the analysis of variance technique for analyzing the data cannot be used without adjustment of the scale. A logarithmic transformation of the data had the effect of normalizing the resulting data by reducing the relative variation from the mean of the few large observations.[3]

Thus all of the analyses of variance calculations were carried out for the transformed scale except for the element, Release of pin, which exhibited homogeneity of variances.

TABLE 1

Analysis of Variance, Log Cycle Times

	df	Sum of Squares	Mean Square	F
S (Subjects)	15	0.33485	0.02232	9.3 F.05 (15,105) < 1.84
Tr. (Treatments)	7	1.14516	0.16364	68.18 F.05 (7,105) < 2.17
O (Order)	1	0.00535	0.00535	6.17 F.05 (1,105) < 3.94
S×*Tr.*	105	0.25248	0.00240	4.42 F.05 (105,105) < 1.53
S×*O*	15	0.00746	0.000497	0.92 F.05 (15,105) > 1.75
Tr.×*O*	7	0.00471	0.000673	1.24 F.05 (7,105) > 2.09
S×*Tr*.×*O*	105	0.57080	0.000543	
Total	255	1.86531		

The partitioning of degrees of freedom requires the separation of Subject effects, Treatment effects, Order effects and the interactions of these main effects. Order effects reflect possible differences between sample one and sample two and as such represent learning effects during the experiment. The Treatment effects can be further partitioned into the main effects and interactions of the experimental variables which are of particular interest in this paper. Table 1 shows the analysis of variance table for cycle times.

Table 1 indicates that there was a significant Order effect but that the first order interactions of Order with Subjects and Treatments yielded F ratios which were at a chance level. Therefore this Order effect is a simple practice effect and does not depend on either Subjects or Treatments. The Subject-Treatment interaction was highly significant. Therefore, $S \times Tr.$ becomes the appropriate error term for testing the significance of Subjects and Treatments, since we are interested in Treatment effects independent of Subjects and vice versa. The *F* ratios for Subjects and for Treatments are both highly significant, indicating that Subjects is a variable and that at least some of the experimental variables have significant effects. The Subject effect is a common result of any experi-

[3] There is a parallel between the structure of these experiments and an information theory model. The increasing area of choice that a subject has as the treatment combinations vary from the simplest level where all of the variables are at their lowest level to the most complex where all of the variables are at their upper levels, represents an increasing amount of information generated. Between these limits we have the other twenty two treatment combinations which present varying degrees of choice to the subject. The decisions to be made by the subject, therefore, come from a widening area of choice as the treatment combinations go from the simplest level to the most complex level. The result of this is that the information generated increases with the increasing complexity of the treatment combinations. The information is given by: $H = \Sigma P_i \log_2 P_i$, where the P_i are the probabilities of making the right choices in the various elements of the experiment. The information is a function of the logarithm of the probabilities. The base of two is commonly used in information theory because of binary code. The empirical and information theory reasons for making the log transformation may differ but they lead to the same result.

TABLE 2

Log Cycle Time, Treatment Effects

	d.f.	Mean Square	F	Effect	Variance
B (Method of Estimation)	1	0.0000131	.00546		
C (Discrimination)	1	0.1489	62.04*	0.0418	0.00000469
D (Hands Used)	1	0.968	403*	0.121	0.00000469
B×*C*	1	0.00150	0.625		
B×*D*	1	0.000581	0.242		
C×*D*	1	0.0211	8.79*	0.0114	0.00000469
B×*C*×*D*	1	0.00548	2.28		
Total	7		*F.05 (1,105) = 3.94		

ment where human beings enter the experiment. Individual differences in performance is the rule and all known motor tasks as well as other kinds of tests of human performance. The Subject effect is not of central interest in these experiments, however. It is Treatment effects independent of Subjects which are of interest and they are displayed in Table 2. The variable *A* (pace) is not shown for cycles because cycle time was completely determined by the rate of feed of part A. The effect of Pace on internal elements is shown in the other four measurements. In computing the *F* ratios in Table 2, the mean square for *S* × Tr. of 0.00240 with 105 degrees of freedom is the divisor.

The most important implication of the results shown in Table 2 is that *B* (Method of Estimation) is not significant. In other words, the actual incomplete Cycle times were forecast by measurements made in the complete cycle and any differences between them were explainable as chance variation. This result occurs in the presence of highly significant *C* (Discrimination) *D* (Hands Used) and *C* × *D* effects, all significant at beyond the 1% level. This indicates an acceptance of the basic hypothesis of the study, that is, that the elements are additive, or that cycle times may be predicted from element times measured in other cycles.

Since *O* (Order) is significant, the effects shown in Table 2 reflect differences for the second observation only, for each treatment combination.

Time for the Added Elements

The basic structure of the analysis parallels that for Cycle times except that Order and its interactions were found to be non-significant. As before *S* × *Tr.* becomes the appropriate error term for Subjects and Treatments. Subjects and Treatments were both highly significant at well beyond the 1% level. Table 3 represents an analysis of the Treatments.

In computing the *F* ratios in Table 3, the mean square for *S* × *Tr.* of 0.00229 with 165 degrees of freedom is the divisor. The variables of *A* (Pace) and *D* (Hands Used) were significant at well beyond the 1% level. The Paced-Unpaced by Hands Used (*A*-*A'* × *D*) interaction was significant beyond the 5% level.

The Added Elements were those elements substracted from the complete cycle to form a forecast of the incomplete cycle. It is to be noted that the variable *C* (Discrimination) is nonsignificant. The point in the cycle where discrimination was required was apparently not close enough to the Added Elements to produce any significant effect. This brings out the important fact that although the time for motor elements interacts, the interaction takes place with elements that are close together in a sequence.

A logical question at this point concerns the magnitude of the Added Elements for if they were minute it could be argued that forecast incomplete cycle times and actual incomplete cycle times were equal because an insignificant element was subtracted from the complete cycle. An examination of the data shows, however, that the average of Added Elements of 1.41 seconds per cycle was about 30% of the incomplete cycle time of 4.64 seconds and about 23% of the average complete Cycle time of 6.05 seconds. This is hardly an insignificant proportion.

Time for Grasp Plus Transport Loading

The basic structure of analysis parallels that for cycle times. Order was significant, however the interactions of Order with Subjects and Treatments were non-significant. The *S* × *Tr.* interaction was significant at beyond the 1% level, and again becomes the error term for testing treatments.

Table 4 represents an analysis of Treatments. In computing the *F* ratios in Table 4 the mean square for *S* × Tr. of 0.00902 with 345 degrees of freedom is the divisor. *A*, *B*, *C*, *D*, and *A*-*A'* × *C* are all significant at beyond the 1% level. The most important fact revealed here is that *B* (Method of Estimation) is a variable. This means that for Grasp plus Transport loaded the elements that followed in sequence affected the time. This is evidence that element interaction existed in the experiment. This

TABLE 3

	d.f.	Mean Square	F	Effects	Variance
A-*A'* (Paced Unpaced)	1	0.00507	2.214		
A (Pace)	1	0.06605	28.843*	−0.0321	0.00000112
C (Discrimination)	1	0.00114	0.498		
D (Hands Used)	1	1.15227	503.175*	0.1096	0.00000075
A×*C*	1	0.00103	0.450		
A×*D*	1	0.00244	1.066		
C×*D*	1	0.00862	3.764		
A×*C*×*D*	1	0.00874	3.816		
A-*A'*×*C*	1	0.00257	1.122		
A-*A'*×*D*	1	0.01199	5.236*	−0.0119	0.00000168
A-*A'*×*C*×*D*	1	0.00096	0.419		
Total	11		*F.05 (1,165) = 3.90		

TABLE 4

Log of Time for Grasp plus Transport Loaded, Treatment Effects

	d.f.	Mean Square	F	Effects	Variance
A (Pace)	1	0.12075	13.39*	−0.02502	0.00000088
A-A' (Paced Unpaced)	1	0.01090	1.21		
B (Method of Estimation)	1	0.07638	8.47*	−0.0201	0.00000059
C (Discrimination)	1	0.73823	81.84*	0.05365	0.00000059
D (Hands Used)	1	1.99054	220.68*	0.10289	0.00000059
$A \times B$	1	0.00073	0.08		
$A \times C$	1	0.00143	0.16		
$A \times D$	1	0.00017	0.02		
A-$A' \times B$	1	0.01865	2.07		
A-$A' \times C$	1	0.04905	5.44*	0.01352	0.00000132
A-$A' \times D$	1	0.01890	2.10		
$B \times C$	1	0.00064	0.07		
$B \times D$	1	0.00763	0.85		
$C \times D$	1	0.02014	2.23		
$A \times B \times C$	1	0.00033	0.04		
$A \times C \times D$	1	0.01517	1.68		
$A \times B \times D$	1	0.00090	0.10		
A-$A' \times B \times C$	1	0.00035	0.04		
A-$A' \times C \times D$	1	0.02905	3.22		
A-$A' \times B \times D$	1	0.00131	0.15		
$B \times C \times D$	1	0.00564	0.63		
A-$A' \times B \times C \times D$	1	0.00133	0.15		
$A \times B \times C \times D$	1	0.00015	0.02		
Total	23		*F.05 (1,345) < 3.89		

strengthens the conclusion that additivity may exist for mean cycle times even though element interaction exists.

Since the actual discrimination took place in the grasp of Part B it is logical that if C were a variable at all, it should be a variable for Grasp plus Transport Loaded.

As with cycle times, the effects shown in Table 4 reflect differences for the second observations only for each treatment combination since Order is significant.

Again, the question of magnitude arises. Grasp plus Transport Loaded contains significant B effects and yet forecast and actual times are equal. Can this be accounted for because the time for Grasp plus Transport Loaded is so small that its effect is masked in a long overall cycle. The average time for the Grasp plus Transport Loaded was 11.8% of the cycle grand mean and was therefore a relatively large element in the cycle.

Time for Release of Part A

The time for Release of Part A occurred in only the complete cycle. It was this element where variances were homogenous and the log transformation was not carried out. The basic structure of the analysis is parallel to that for Added Elements in that the variable O and its interactions were all nonsignificant. The interaction $S \times Tr.$ was highly significant and well beyond the 1% level and was used to test the significance of Subjects and Treatments.

Table 5 represents the analysis of treatments. In Table 5, the mean square for $S \times Tr.$ of 1.66 with 165 degrees of freedom is the divisor. The variables A (Pace) and D (Hands Used) are both significant at beyond the 1% level. The interactions $A \times C \times D$ and A-$A' \times D$ are both significant at beyond the 1% level. The nonsignificance of C (Discrimination) may again indicate that to be affected by the C variable, an element must occur close to the point of discrimination in the sequence of elements. The significance of $A \times C \times D$ in the absence of any main effect of C may indicate that discrimination exerts its effect on distant elements only as a stress load builds up, i.e. in the presence of increased pace and a more complex motor pattern (the use of both hands).

Time for Position Plus Release of Part B

The time for Position plus Release of Part B was measured only in the incomplete cycle. The basic structure of the analysis is also parallel to that for the Added Elements in that the variable O and its interactions were all nonsignificant. The interaction $S \times Tr.$ was highly significant at well beyond the 1% level and in Table 6 it is used to test the significance of treatments.

The results of Treatment effects on the element Position plus Release are simple in that the only significant variable was D (Hands Used). Apparently the pace level cannot hurry a person in performing the positioning element. The variable C (Discrimination) is non-significant even though the Position plus Release element was adjacent to the Grasp plus Transport Loaded element where the discrimination actually took place.

General Conclusions

The main conclusion to be drawn from the experimental results is that additivity holds for the conditions of these experiments. This conclusion tends to bear out the results found by Stiling's simple knob-turning task (21) and to refute the results of the key-tapping experiment of Ghiselli and Brown (9). Since Stiling reports that Ghiselli's and Brown's experiment was based on only one subject the

TABLE 5

Time for Release, Treatment Effects

	d.f.	Mean Square	F	Effect	Variance
A-A' (Paced Unpaced)	1	2.03	1.22		
A (Pace)	1	26.49	15.96*	−0.64	0.00081
C (Discrimination)	1	6.27	3.78		
D (Hands Used)	1	140.09	84.39*	1.21	0.00054
$A \times C$	1	0.76	0.46		
$A \times D$	1	1.99	1.20		
$C \times D$	1	0.0007			
$A \times C \times D$	1	8.54	5.14*	0.37	0.00081
A-$A' \times C$	1	1.33	0.80		
A-$A' \times D$	1	7.51	4.52*	−0.267	0.00054
A-$A' \times C \times D$	1	5.87	3.54		
Total	11		*F.05 (1,165) = 3.90		

TABLE 6

Log Time for Position plus Release, Treatment Effects

	d.f.	Mean Square	F	Effect	Variance
A-A' (Paced Unpaced)	1	0.00371	0.569		
A (Pace)	1	0.00224	0.343		
C (Discrimination)	1	0.01323	2.029		
D (Hands Used)	1	1.57184	241.080*	0.12796	0.00035
A×C	1	0.01003	1.538		
A×D	1	0.01632	2.503		
C×D	1	0.00443	0.679		
A×C×D	1	0.00219	0.336		
A-A'×C	1	0.01129	1.732		
A-A'×D	1	0.00173	0.265		
A-A'×C×D	1	0.01944	2.982		
Total	11	*F .05 (1,165) = 3.90			

strength of a general conclusion that additivity holds is improved.

Are the results of these experiments broadly applicable to all kinds of manual work? No definite answer can be given. It is important to point out in this regard, however, the nature of the task used is representative of light assembly tasks and both sensory and motor variables were included.

The essence of these results indicate that the general construction of existing standard data systems allows cycle times to be forecast from mean element times measured in different cycles, provided that the sampling procedure used in developing the mean element times was adequate.

Conclusions Ancillary to Additivity

An interesting observation results from an examination of the effects of *A-A'* (Paced-Unpaced) for the four measurements taken on elements within the cycle. In no case was *A-A'* significant. It does not seem appropriate to extend this result to manual cycles in general. The *A-A'* effect represents a comparison of the unpaced with the average of the two-paced levels. It may well have happened that the average of the two-paced levels selected matched the unpaced level. Since Pace was a variable for all measurements taken except Position plus Release it seems illogical to assume that *A-A'* would have been generally insignificant if other pace levels had been used.

Pace itself was a significant variable for all internal elements except Position plus Release of the bushing (incomplete cycle). It is interesting to speculate why the element position plus release should be an exception to the general pattern. Positioning elements generally require considerable attention which could logically result in a lesser response to the increased pace. Since no response at all was observed, it seems that further research would be appropriate on this subject.

The variable of discrimination was significant for the cycle and for the element Grasp plus Transport Loaded (where the discrimination actually took place), but was not significant for Release, Position plus Release, nor for the Added Elements. Discrimination seems to be effective as a variable at the point of discrimination in the cycle but does not seem to affect the elements which follow it. Although the transport empty of the bushing was not measured it was probably affected by the discrimination. These general results are in contrast to those found by Simon and Smader (14). In their experiment, the subject grasped a washer from a bin and placed it on one of twelve upright pins. On half of the trials, the subject placed the washers on the pins with red dots up and on the other half, the washers could go on any way. Their results indicated that the discrimination was effective on all elements. Actually, however, their experiment confounded a discrimination variable with a motor variable for extra manipulatory elements were required to orient the red dot up. The motor variable may well have been the one that interacted with the other element times. The results of the experiment reported here indicate that this may have been the case.

The contrast between the use of one hand vs. both hands was significant for all measurements made. This general result agrees with results reported by Barnes, Mundel and MacKenzie (6).

Future Research

With regard to additivity it would seem fruitful to carry out future experiments which would extend to variables not included in the experiments reported here, for example, different classes of fit for positioning elements, distance effects, different grasping conditions and so on. If the additivity hypothesis can be accepted generally, then a large research project remains to be done in developing a workable standard data system for all classes of motion elements. This should parallel anthropometric studies of body size, weight, etc., in that large samples of the working population of men and women would be required. The results should be expressed in terms of mean time value and variance. The resulting standard data system could be used as a handbook of data by engineers designing machines in work places, for estimating labor costs of proposed parts and products, and as an aid in scheduling job lot parts in a production plant.

Future research into pacing effects seems justified since little is now known about how the structure of element changes with increasing pace level. Our specific study was suggested above, pacing effects on positioning elements.

In the present study it was noted that the variable Discrimination had no effect on the element's Release of Pin, Position plus Release, or the Added Elements. Future research could be directed at the determination of how many steps away from the point of discrimination interaction is present.

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Industrial Engineering Today*

The following broadcast was made over WABC, the New York City Station of the American Broadcasting System on May 14, 1957. It was intended to call attention to the then forthcoming National Convention and to make the general public better acquainted with Industrial Engineering. The latter purpose could not, of course, be met by discussing the subtleties of the subject nor employing its jargon.

It is hoped that readers will find this article useful in introducing friends, employers or prospective students to Industrial Engineering. Also it may serve as an example of a successful attempt to talk publicly about a subject that becomes intelligible only when the greatest care is exercised.

The Journal reprints the transcript with only minor editing to keep the spontaneous flavor of the broadcast which was an unrehearsed conversation.

ANNOUNCER WABC, as part of its program to keep its listeners informed and enlightened on progress in modern business, presents this special broadcast in connection with the Eight National Conference of the American Institute of Industrial Engineers, to be held in New York City at the Hotel Statler on May 16 and 17. The Institute, an engineering society, is devoted solely to the profession of Industrial Engineering.

Tonight, we have with us Mrs. Gene Weeks, of Gene Weeks and Associates, and Dr. Herbert Jacobs, of Dunlap and Associates, Inc., Industrial Engineers, who will discuss some examples of their work and what is meant by Industrial Engineering. The discussion will be moderated by Professor Frank Gryna, of Rutgers University, one of the co-chairmen of the Conference.

Professor Gryna, could you give us a definition of Industrial Engineering?

PROF. GRYNA Yes. Industrial Engineering is concerned with the design, improvement, and installation of integrated systems of men, materials and equipment. . .

MRS. WEEKS Couldn't we break that down a little bit, Frank?

PROF. GRYNA Well, Gene, suppose we first start by talking about the field of work simplification. Now, you have done quite a bit in that area within the banking industry. Could you talk about that for a moment?

MRS. WEEKS Well, yes, exactly as the term implies, work simplification is a technique which makes it easier for people to do their jobs. One of the special projects we are working on is to rearrange the money in the teller's cash drawers so that those bills which he uses most frequently will be right in front and easy to put his hands on when they are needed. There has been a good deal of research on allied problems, particularly in the fields of business machines, now that bankers are eying new electronic systems, but naturally we feel that application is more limited in banks than it is in industry. Herb has probably seen more chances to extend work simplification to machines and more complicated technical equipment when prepositioning is vital and you want to get your work through as fast as possible.

PROF. GRYNA Suppose we extend this to machines. Is there any fear that the machines might replace the man eventually?

MRS. WEEKS Oh! Not by a long shot. The more mechanized industry has become, the more jobs have been created frequently jobs that are much more interesting to do and which require higher skills, so that you get the chance to bring people along and relieve them of routine operations such as most people associate with factories, like pushing a button or pulling a lever. In fact, statistics on that show that when the population went up 20%, jobs went up about 70% in the manufacturing industry.

DR. JACOBS Our listeners might recall that the Gilbreth's of the *Cheaper by the Dozen* fame were very active in the field of work simplification.

MRS. WEEKS Well, as a matter of fact, I guess they are the most celebrated people in it, and they really brought it down to terms that people can understand. Frank Gilbreth has a famous experiment on how many strokes it takes to shave himself, and whether he pulls the razor up or pushes the razor down his cheek, while his wife, Lillian, (who is perhaps more famous for getting her family together as fast as possible) brought engineering into the kitchen so she could finally get a sink designed for her size and use.

PROF. GRYNA Very recently the field of Industrial Engineering has broadened out to include many, many new techniques. Herb, you have done quite a bit of work in this area of operations research. What is operations research?

DR. JACOBS I am very glad you brought the subject up, because I believe that operations research will become an important part of the Industrial Engineering of the future. Operations research is concerned with the study of major decision problems. These may be problems of capital acquisition or problems in the design and operation of large scale systems. Operations research has been successfully applied in such diverse areas as the development of military tactics, the scheduling of industrial production, and the allocation of sales effort

* A transcript of a broadcast in connection with the Eighth Annual National Conference of the AIIE.

For many years, Industrial Engineering concentrated very heavily on the application of time study and the development of job methods. One of the consequences of this was that Industrial Engineers tended to become known as "efficiency experts". I am very happy to observe that some of the recent developments in this field, operations research in particular, are helping to get Industrial Engineers away from too much concern with operations in the small and are beginning to involve them in larger decision problems some of which even stand to affect the conduct of our entire industrial society.

PROF. GRYNA How about a few examples, Herb?

DR. JACOBS Well, one of the best examples that I can think of is in the operation of a typical supermarket. Now you or I, as consumers, for example, have frequently done our shopping on a Friday evening or Saturday, and we have had to stand in line. Maybe there have been five or six people ahead of us waiting to check out their merchandise so that they could proceed on home. Whenever this has happened to us, we, of course, have become quite exasperated and upset by the situation. But look at this from the supermarket's point of view. The fewer check-out stations which they have in operation at any time means essentially that they can operate at a lower total cost. Obviously some kind of compromise is required between lower operating costs and unhappy customers. Operations research in this particular case concerns itself with finding the right number of check-out counters or stations to have working at any one time so that it doesn't cost too much to run the store, and so that customers won't become too unhappy by having to stand in line too long. This is an oversimplified example of what might be considered an optimization problem. Similar problems occur in the management of inventories, the programming of machine production and even the operation of truck fleets.

MRS. WEEKS Could you sum it up and say that operations research is really the best analysis that you can use to get facts as a basis for decisions?

DR. JACOBS Yes, operations research is really the science or engineering of decision. Many large companies, for example, are faced with problems such as where to put a new plant, what kind of earth-moving shovel to buy to perform a particular mining operation, how to control or program their production so that their inventories don't become too large. These are typical important decisions, problems sometimes involving hundreds of millions of dollars of cost or capital investment. In treating problems of this type, rules of thumb, intuition, and "seat of the pants" judgment simply aren't good enough.

PROF. GRYNA Certainly one of the fundamental problems of the manager today is this question of decision making. Gene, can you tell us how this enters into the field of cost control as you have seen it in the banking industry?

MRS. WEEKS Well, I guess one of the biggest decisions the banks have been facing and are still facing is this question of dividends in the savings bank field, for instance. Competition being what it is, when a fellow across the street decides to go up to 3 or $3\frac{1}{4}$ %, it is pretty inevitable that you have got to find out if you can do the same thing. The operating cost of mutual banks is primarily the cost of their services, with no profits in the usual sense of the word and most of their income derives from mortgages with interest rates that are pretty well controlled in our present economy. It is therefore important to see that your costs are pared as closely as possible so that you can pay this dividend to people.

PROF. GRYNA Excuse me, Gene, just let me interrupt you for a moment. Many of our listeners may wonder why a woman is speaking here as an Industrial Engineer. Now there aren't many women in the profession of engineering today. Maybe you can tell us a little-bit about why you became an Industrial Engineer or why you feel that women can do this kind of work well.

MRS. WEEKS I'd rather answer the question in general. I think that women have a very positive contribution to make to this field. At the risk of bringing down on myself some comments from the men here, I think that women do understand people more, and the field of Industrial Engineering is very basically people in the work place. Basic Industrial Engineering problems usually revolve around how you get people to work together and how you get your communication through, how you teach them and train them to do an entirely new job and what happens when you really upset their apple cart on the work scene in order to introduce new techniques or new machines.

DR. JACOBS Would you say that this is kind of an applied woman's intuition?

MRS. WEEKS Well, I was trying to avoid that term, Herb, because I'd like to think that Industrial Engineering is more than intuition. It is really an application of scientific methods to the work scene in order to improve your methods and make people happier on the job.

DR. JACOBS The last experience that I had in connection with women in the field of Industrial Engineering took place shortly after my first daughter was born. I worked out a very careful schedule for preparing the baby's formula so that it could be performed in 40 minutes instead of an hour and a half. I had no sooner completed this study and made what I thought was a very effective contribution to the field of Industrial Engineering than my wife insisted I might just as well take over the continuing chore of preparing the baby's formula by way of testing the feasibility of this scheme.

PROF. GRYNA The Industrial Engineer is certainly concerned with the field of human relations, and we have come up with a new term in the field called "human engineering." Now Gene, would you like to comment on that?

MRS. WEEKS Well, the term is new but the field is pretty old. You have always had people on the scene but

perhaps our constant preoccupation with people is new. Maybe one of the factors is that the labor supply is a little bit short and a little bit expensive, so the best use of those people becomes a rather important item on the industrial scene. Although there is a lot of research on this, on just what makes people tick and how they are motivated while they are doing things, it is still rather interesting to find the human aberrations that occur in a field that is supposed to be pretty well controlled, such as quality control. One of our recent experiences took place in Italy where they were conducting a complete inspection of a certain product; actually it was inspected what we engineers would call 300%. In other words, it was completely inspected three times by 3 different people, and still 50% of the items were being rejected at the end of the line because they weren't working right. In other words, you had a human failure along the line even though your system was supposed to be perfected to catch everything.

DR. JACOBS—They needed an inspector to inspect the inspector.

PROF. GRYNA—Wouldn't it seem logical that if we looked at every single unit that we produced, we would find all of the defective units?

DR. JACOBS—Well, Frank, why don't you say something about that and answer your own question? I know you have had a lot of experience in the field of quality control.

PROF. GRYNA—Well, Gene mentioned that example over in Italy. We had to end up with 300% inspection, and very frequently we find that if the inspection operation has any degree of monotony in it, the human being just isn't able to find all of the defective units, so that looking at all the units we cannot expect to find all of the defectives.

DR. JACOBS—Frank, excuse me, I just wondered if it wouldn't be worthwhile to turn this discussion for a moment to the subject of training Industrial Engineers in the future. The engineering field is very attractive to many of our people now in high school, and many of them must wonder what kind of opportunities are available in this particular field. I mentioned a few of the ideas involved in operations research, which is really a special aspect of Industrial Engineering. What kind of training and preparation can our people look forward to and what kind of opportunities are there here?

PROF. GRYNA—Well, speaking as one from the academic world, within the past half dozen years or so the Industrial Engineering profession has really spread out among many many different universities throughout the country. There are quite a few schools here and abroad that offer courses in this general area.

DR. JACOBS—Let me just add a note to that and say that many of our Industrial Engineering Departments are now offering special courses in operations research, statistical quality control, economic analysis and other areas. Much more preparation is being required in mathematics, sciences, statistics, and economics than engineers have traditionally been exposed to during their undergraduate training.

MRS. WEEKS—I hope that they are still having some courses that deal with leadership too, because one of the roles of the Industrial Engineer is to direct the team of scientists that have to work on some of the highly mechanized equipment our factories are turning out.

DR. JACOBS—Yes, I think it is quite significant that more and more frequently Industrial Engineers are helping to make important decisions, advising top management on major decision problems. The role of the Industrial Engineer in our industrial society is becoming increasingly important as we concern ourselves with the study of large-scale operations in which substantial amounts of capital are invested.

DR. JACOBS—How about the role of the Industrial Engineer just as he graduates from school? Where does he fit in with an industrial company?

PROF. GRYNA—Well most young Industrial Engineers must look forward, I think, to a period of preparation, of pick-and-shovel work while they are learning the ropes, learning how to handle themselves, learning how to solve problems. I think that we must expect our young people to go through this sort of training and preparation for more important responsibilities.

MRS. WEEKS—A recent questionnaire to the membership of the American Institute of Industrial Engineers showed that it covered such a wide field that it is awfully hard to pin down exactly where an Industrial Engineer begins, either in the product he is making or in the job that he is doing. It covers everything we have spoken of today and a lot more besides in the field of budgets and training and personnel work.

DR. JACOBS—We might just mention, too, that a number of papers on the newer techniques and newer aspects of Industrial Engineering will be presented at this forthcoming conference of the AIIE.

PROF. GRYNA—Well, I see we are running out of time. I hope the discussion this evening has stimulated your interest to the point where you would like to know more about our profession.

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The Economics of Work Performed on a Numerically Controlled Machine Tool[1]

By Thomas V. Atwater, Jr.

Vice-President and Treasurer, Product Development Corporation, Boston

and Robert H. Gregory

Assistant Professor of Industrial Management, Massachusetts Institute of Technology

The technical feasibility of numerically controlled machine tools has been established within the past five years. An early and extensive program in this field was the numerical-control project of the Servomechanisms Laboratory of the Massachusetts Institute of Technology.

The concept underlying numerical control is to utilize explicit instructions to control all operations of a machine tool during operation. This involves 1. micro-instructions to specify amount of movement and permissible time for cutter, or work piece, or both, 2. a director to interpolate motion and time specifications into micro-instructions for the machine, 3. control equipment (servomechanisms) at the machine to execute the micro-instructions, and 4. a feedback system to report machine execution of micro-instructions.

By way of contrast, tracer controlled machine operations rely upon complete or partial analogs of the work piece and some device attached to the machine to enable it to follow the analog.

Numerical control uses digital information (numbers) stored on punched paper or magnetic tape to specify movements (in increments measured in X, Y, Z axes and rotation), and appropriate time for movements for machine instruction and control.

In this project a three-motion vertical milling machine was equipped with servomechanisms and an electronic director, as shown in Figure 1, capable of guiding the machine tool automatically through complicated machining programs.

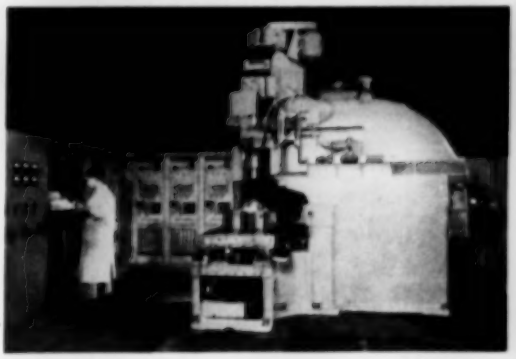

FIG. 1. Numerically Controlled Milling Machine

Problem of Economic Analysis

An evaluation program was undertaken following the formal demonstration of this machine system in September, 1952. The Servomechanisms Laboratory performed actual machining jobs for customers to obtain comparative cost information and operational and maintenance data under something resembling production conditions. While the Servomechanisms Laboratory personnel were confident of their ability to analyze the technical experience data, the authors, staff members of the School of Industrial Management, undertook an economic appraisal of the work pieces performed.[2]

Because the original project was sponsored by the Air Force, attention was first directed to the field of military aircraft production in which the AMC goals supplant the familiar industrial investor's question, "Does the new technique allow an increase in net profit through an increase in revenue, a decrease in cost, or both?" The Air Force measures cost in traditional terms, but it measures revenue only in terms of air power, an elusive mixture of number, types, condition, and performance of aircraft. An

[1] This article is a summary of a report *Economic Studies of Work Performed on a Numerically Controlled Milling Machine* (Engineering Report No. 18) made possible through support extended the Massachusetts Institute of Technology, Servomechanisms Laboratory, by the United States Air Force, Air Material Command.

[2] The technical details and some of the history of this project are described in the *Final Report, Construction and Initial Operation of a Numerically Controlled Milling Machine, Part I*, dated September, 1952, and Part II, dated May, 1953.

evaluation of the effect on these factors of extensive application of numerical control was clearly beyond the scope of our study. As a result, we were forced to limit the study to comparative costs and almost totally ignore the important performance features of numerical control for which we could get no quantitative data.

Costs Affected

Among the cost factors affected by the advent of numerical control are the following:

Part costs:

1. Direct machine time, per part.
2. Machine setup time.
3. Tooling costs.
4. Design and engineering costs.

Productivity:

1. The quantity of a single part produced per unit time.
2. The quality of parts produced, and scrap and waste ratios.
3. The variety of parts produced.
4. The variety of parts that can be handled by a given tooling organization.
5. The variety of parts that can be handled by a given production engineering group.

Capital costs:

1. The cost of the equipment.
2. Personnel training costs.
3. The cost of readjusting a work force to optimize the new process.
4. The cost of retiring existing equipment.

The Servomechanisms Laboratory files yielded reasonably complete and detailed information in two categories: 1. the specifications for some 76 parts that had been produced, and 2. the expenditure of time for each step in the small-quantity production of each of the above parts by numerical control.

Areas of Uncertainty

There was, however, no reliable quantitative information in the following areas:

1. Reproduction cost of numerical control equipment.
2. Effect of numerical control on the productivity of a production system.
3. Which part or group of parts produced might be considered representative of aircraft production.
4. The relative efficiency of the laboratory operation, particularly in the areas of programming and tooling in which laboratory personnel had no previous experience.
5. The manufacturing costs of cooperating companies which furnished parts to the laboratory for production study purposes.

Of these factors, the last appeared to be the easiest to determine and was chosen as a starting objective. A comparison of production costs also has the advantage that if the new method clearly permits a reduction in total production costs, its economic success is almost assured, and further study may not be required.

It was therefore decided that the initial objective would be to try to answer the question: Did Servomechanisms Laboratory costs indicate that numerical control techniques were sufficiently developed to warrant industrial adoption by aircraft makers?

It was soon evident, in the machine-evaluation program, that, while it was easy to get sample workpieces, it was extraordinarily difficult to obtain reliable data on current and comparable costs of workpieces selected. There were many different reasons for this difficulty, including these causes:

1. Many parts were experimental and had not been produced by any method other than numerical control.
2. Many parts had not been produced with comparable accuracy.
3. It was often impossible to evaluate the effect of peripheral operations such as pre-machining and hand finishing.
4. Many companies were extremely reluctant to release their own production cost figures unless they were camouflaged by overhead and mark up allowances.
5. Most of the parts studied were diverted from normal production channels by individuals who were too remote from actual production to be able to estimate production costs accurately.
6. Company accounting practices often did not permit a determination of cost for a single part from existing records, and neither funds nor manpower were available in the cooperating companies to obtain such data by special studies.

As a means of sidestepping such difficulties of obtaining data, it was decided to obtain estimates of production costs from independent job shops for the pieces studied. Ten of the sample workpieces machined in the laboratory were chosen as reasonably representative of the range of work performed. Figure 2 shows the ten pieces selected.

Estimates of man and machine times to make each of the ten pieces selected were obtained from one or more of ten companies referred to hereafter as companies A to J. Each cooperating company (as well as a number of others that we approached but which did not, for a variety of reasons, work with us) was asked to supply detailed estimates of operations, manpower, and machinery for making a piece. Each company was offered payment at going market rates for its estimating services (seven of the ten accepted such payments), and we carefully explained that no jobs would be assigned as the result of estimates furnished. We used every means available to try to keep the estimates from being influenced by a company's need either to obtain additional business for its shop or to restrict the amount of business that it obtained.

We furnished blueprints, pictures and sample pieces to cooperating companies to study in making their estimates. They were asked to describe the production process and to estimate the time to make each piece in small (one to five) and moderate (25 to 30) quantities. We concentrated our attention on those operations required to achieve as nearly as possible the same results as were achieved by the Servomechanisms Laboratory operations.

Cost Rates and Job Studies

Our original study of the ten representative jobs developed comparative cost information by estimates on each

job obtained from at least one independent machine shop. For brevity, the full data for only one job, the engine mount, are presented here. In a later section, the nature of each job and production information is briefly described.

In our full report, operations are listed in enough detail to show separately make-ready and piece-production costs. Make-ready costs, for numerically controlled production, are classified as:

1. Select a method of manufacture.
2. Compute desired contour, tool center corrections and tool center loci.
3. Prepare tape, including conversion of tool center loci from decimal to binary form.
4. Plan, design, and make holding fixture.
5. Test and debug program and fixture.
6. Set up machine.

The operations done by the Servomechanisms Laboratory not involving its milling machine are priced at the average rate of $5 per hour to cover wages and related costs (supplies, other machines, etc.). Studies of individual wage rates for the various job skills involved in make-ready and operation at the Servomechanisms Laboratory convinced us that an average rate would serve quite well to cover all the skills involved. Although economies may arise from using less skilled people for some operations, they are not considered here.

In addition to labor and related costs, $5 per operating hour is included for the time that the numerically controlled milling machine was used (fixture and program testing, machine setup, piece setup and metal cutting). This amount was estimated as follows:

Cost of a numerically controlled machine tool (director, servomechanisms, and machine)	$60,000
Life, operating 2,000 hours per year, 10 years	
Depreciation per hour	3
Additional operating costs (power, maintenance, etc., but excluding operating labor included in wage costs)	2
Operating cost of a numerically controlled machine tool, per hour	$5

This estimated cost of operating numerically-controlled machine tools of the type under discussion is, of course, subject to question. The capital cost of the original machine and director developed by the Servomechanisms Laboratory is not precisely known. Even if known precisely, such cost would not be completely suited to our purposes because an economy study dealing with adoption by industry involves the cost of the commercially available model, not the present experimental prototype.

The estimated cost of $5 per hour for labor and related costs not involving the machine and $5 per operating hour for the numerically controlled machine tool itself are used in assessing the man and machine costs reported by the Servomechanisms Laboratory for the job discussed in this section. If these rates are not considered realistic in an industrial environment, they can be converted to a desired rate or rates.

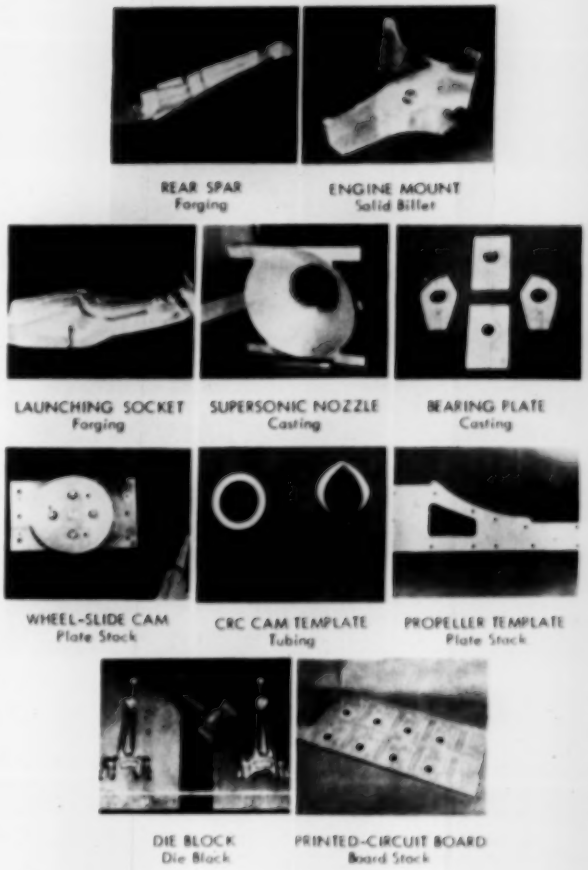

FIG. 2. The Ten Sample Points

For cooperating machine shops we classified the operations as relating to job make-ready or to production of the individual piece. Manual operations (designing, drawing, calculating, etc.), were priced at $5 per hour to cover wages and overhead. Machine operations were also priced at $5 per hour to cover all costs, including an operator. This average rate was thought appropriate for the cooperating companies (except for one whose estimated cost of $6 per hour was substituted) considering wage rates actually paid, types of machines involved, and overhead structures of the companies furnishing information.

Engine-Mount Fitting

The engine-mount attachment fitting considered here is an example of a "hogout" from a forged billet of 14S-T6 aluminum alloy, approximately 5" x 8" x 8". A schematic print of the piece is shown in Figure 3. Pictures of a partly finished piece and finished pieces are shown in Figure 4.

This piece was designed to be made from a forging by

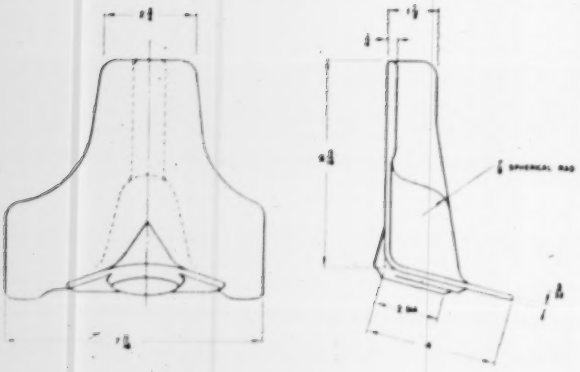

FIG. 3. Print and Engine Mount Fitting

machining the mounting surfaces and holes only. However, the work in sinking the dies to make the forgings involved about four months elapsed time. In order to speed manufacture, it was decided to make 33 pieces from solid billets by machining all surfaces. As it turned out, less elapsed time was required for completely machining the desired pieces than for sinking the dies and machining merely part of the surfaces.

Information was obtained from the Servomechanisms Laboratory and two machine shops concerning production of this engine-mount fitting.

Servomechanisms Laboratory

The Laboratory used its numerically controlled milling machine for all operations except the original facing of one side of the billet, drilling three holes for hold-down clamps, and drilling-boring the holes with shoulders. Some of the operations, especially major metal removal, might have been performed more economically with a metal saw, if available.

The complete program required eight fixtures, six for use on the milling machine and two for use on the lathe in drilling and boring holes. The fixture problem was acute, because the finished surfaces were not at right angles to each other and required use of a universal tilting table in six operations. Briefly, the fixtures located the piece for each operation from three reference surfaces, one in each plane. These surfaces were machined in the first operations on the milling machine and were maintained throughout the various operations as long as necessary to provide proper location of the work piece. In the last two operations the center rib was used in place of one of the surfaces.

Twenty operations, thirteen of which were done on the milling machine, were required to machine the billet into a finished piece. A complete list of the operations indicating the machine used for each is shown in Figure 5.

The costs for make-ready and per-unit cost of machining 33 pieces in the Laboratory (excluding the cost of drilling and counter-boring two holes and filing-polishing which together accounted for approximately $640 of fixtures and $42 of machining by the lab) are shown in Table 1.

The programming time of approximately 278 hours was required to determine the exact path of the tool from the dimensions given on the drawing. This included computation of the equations for intersection of adjoining spherical and cylindrical surfaces. Graphically determined tool-center loci were used in shaping the cone.

The total cost for the Labratory to machine the first piece was $5,598. About half of this amount was spent on fixture manufacture and half on programming and tape preparation. The cost per piece, after the first, was quite small at only $80 ($54 for milling machine and $26 for other operations). These costs are plotted in Figure 6.

Company I

A small machine shop near Boston estimated the man-machine hours required to cut this fitting from solid metal.

TABLE 1

	Time Hours	Cost per Hour Labor and Overhead	Numerically Controlled Milling Machine Costs	Total Cost
Programming				
General planning	24	$5.00		$ 120
Determining tool-center loci	254	$5.00		$1270
				$1390
Tape preparation				
Tape code preparation	152	5.00		760
Tape punching, checking and correcting	78	5.00		390
Dry run and debug program and fixture	25	5.00	$5.00	250
				$1400
Fixtures				
Design and check	72	5.00		360
Detail	43	5.00		215
Manufacture	400	5.00		2000
				$2575
Machining on numerically controlled milling machine				
Setup fixtures (once per run)	12	5.00	5.00	120
Setup, per piece	.6	5.00	5.00	6
Metal cutting, per piece	4.8	5.00	5.00	48
				$ 174
Other operations				
Setup fixtures (once per run)	6.5	5.00		33
Setup, per piece	.5	5.00		2
Metal cutting (bore, drill, etc.)	2.9	5.00		15
Hand finishing	1.8	5.00		9
				$ 59
Total				$5598

The cost for operations to give results comparable to those obtained by the Servomechanisms Laboratory was estimated as shown in Table 2.

TABLE 2

	Time Hours	Cost per Hour Labor and Overhead	Total Cost
Make ready			
Planning	Negligible		
Fixtures	Negligible		
Machining			
Piece set up	8	$5.00	$ 40
Machining	21	5.00	105
			$145

The machines involved included a metal saw to rough-cut the block to approximate shape, and a milling machine and a tilt-head mill to cut the first piece. For production in larger lots, say 20 to 30, the first piece was placed on a milling machine with contour tracing attachment and three fixtures, estimated to cost $450 were planned to reduce set up time per piece. Set up of the fixtures was estimated to take about as long as the set up for one piece described above. Thereafter, machining operations could be done faster for each piece. Pieces run with this tooling were estimated to take about 50 percent as much handling and machining time as the first one.

The estimated costs for making up to 30 pieces with the machining time per piece expected to decrease throughout the lot, can be summarized as shown in Table 3.

The costs for this company to machine one piece and to machine a lot of 30 are plotted in Figure 7.

As pointed out previously, the manufacturing procedure

TABLE 3

	Time Hours	Cost per Hour Labor and Overhead	Total Cost
Make ready			
Planning	Negligible		
Fixture design and make			$ 450
Machine first piece			
Piece set up	8	$5.00	40
	21	5.00	105
Machine next 9 pieces at 90% of unit machining time 9 × $105 × .90			850
Machine next 10 pieces at 75% of unit machining time 10 × $105 × .75			788
Machine next 10 pieces at 60% of unit machining time 10 × $105 × .60			630
Total cost for 30 pieces			$2863

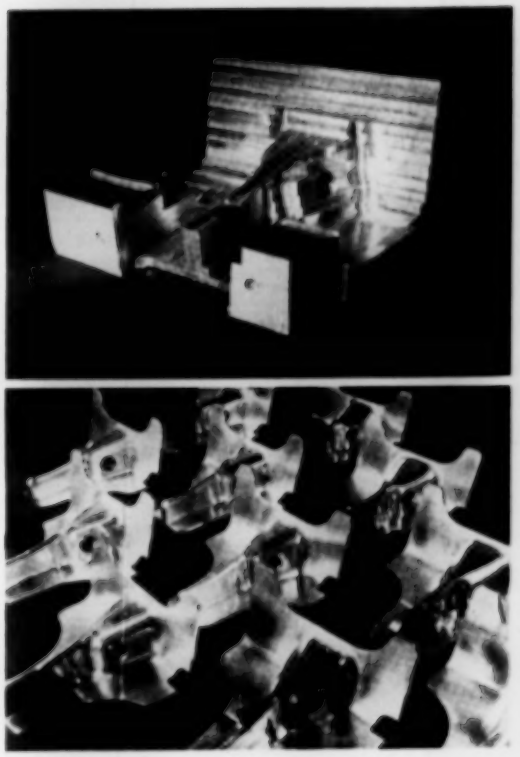

FIG. 4. Two Views of Engine Mount Fittings. Partially machined, at top. Completed fittings, below.

actually followed by the Laboratory and the plan proposed by the machine shop consisted of machining the engine-mount fitting from a forged block of aluminum. The original specifications for this engine-mount fitting were to machine it from a forging with substantially the desired shape. It was thought desirable to explore the costs of making dies and using them to forge this piece. A composite forging-plus-maching estimate for this part is summarized in the following section.

Summaries of Comparative Costs

The information obtained from one detailed study was presented above for the engine mount. A brief evaluation of the data obtained for the other nine jobs illustrated in Figure 2 seems desirable even though the detailed information is omitted for brevity.

The principal metal-cutting areas represented are 1. machining to specifications from billet, bar stock, or extrusion; 2. finish machining castings and forgings; 3. profile and three-dimensional milling of cams and 4. templates; and 5. miscellaneous jobs such as diesinking. We do not have enough observations within each area to draw firm conclusions, even aside from the problems of representativeness of the firms and work pieces included. However, the studies may be taken as roughly indicative of

TOTAL COST

Oper. No.	Machine	Tool	Fixture	Description of Operation	Time - Minutes		
					Setup (per run)	Handling (per piece)	Cutting (per piece)
1	Lathe	-	Chuck	Face one 8" x 8" side of raw billet. Square billet if necessary.	60	5	40
2	Drill	-	Setup	Drill three holes 3/4" diameter, 5/8" deep for hold-down clamps.	60	10	5
3A	NC MM	2" dia. 6 flute end mill 1 3/4" long	EL008	Rough steps in billet to remove excess material.	45	3	27
3B	NC MM	2" dia. 3 flute end mill 6" long	EL008	Rough steps in billet to remove excess material.	--	3 tool change	35
4	Lathe		Lathe Fixture No. 1	Rough bore 3-step hole in vertical flange.	75	5	70
5	Drill		Setup	Drill 2-step hole at 90° to bored hole done in operation 4.	60	4	15
6	NC MM	2" dia. 6 flute end mill 4" long	EL009 Tilt Table 5°50'	Machine outside of horizontal flange leaving 0.050 for finish cut.	195	-	22
7	NC MM	2" dia. 6 flute end mill 4" long	EL010 Work Platform	Machine inside of flanges to approximate contour of finished piece.		-	
8	NC MM	1" dia. 4 flute end mill 4" long	EL011 Tilt Table 8°55'	Further machine inside to approximate contour. (1/2" thick rib spherical dia., remove steps.)	60	-	45
9	NC MM	1" dia. 4 flute end mill 4" long	EL010 Work Platform	Rough and finish machine surfaces of 1/2" thick rib and inside of horizontal flange.		-	
10	NC MM	1/2" dia. 2 flute ball mill 2 1/4" long	EL010 Work Plat. EL011 Tilt Table flat	Machine 1/4" radius between surface of 1/2" rib and inside of horizontal flange. Machine 1/2" radius on end of 1/2" rib.	105	-	12
11	NC MM	1 1/4" dia. 2 flute	EL010 Work Platform	Contour sphere and sides of cylindrical rib. Machine 1/2" radius between rib and adjoining flat surfaces.	--	5	40
12	NC MM	end mill 7° taper to 1" ball end	EL011 Tilt Table 7°43'	Finish machine inside of vertical flange	75	3	20
13A	NC MM	2" dia. 2 flute end mill 1 1/4" long	EL009 Tilt Table 5°50'	Finish machine outside of horizontal flange	105	3	7
13B	NC MM	1/2" dia. 2 flute end mill 2 1/4" l.g.	EL009 Tilt Table 5°50'	Contour cone on outside of horizontal flange. Machine finished outline of horizontal flange.	15	5	30
14A	NC MM	1" dia. 2 flute end mill 3/16 by 45° chamf.	EL012 Tilt Table 14°43'	Finish machine outside of vertical flange. (Including contouring triangular and circular bosses.)	105	6	45
14B	NC MM	1" dia. 2 flute end mill 1/32 rad.	EL012 Tilt Table 14°43'	Machine slot in edge of flange.	--	5	2
15	NC MM	1" dia. 2 flute end mill	EL012 Tilt Table 5°50'	Machine recess in outside of vertical flange.	15	2	4
16	Lathe		Lathe Fixture No. 2	Finish bore 3-step hole in vertical flange.	75	5	40
17	Drill	-	-	Drill 1/8" hole for cotter pin.	60	3	1
	Totals in Mins.						
	All Machine Time				1110	67	460
	NCMM Time				720	35	289
	Other Machine Time				390	32	171
18				Hand Finish			110

FIG. 5 Program Summary for Machining the Engine Mount Fitting

relative efficiencies in each area, and the reader is always free to modify our interpretation by adding his own detailed comparative data.

Machining from Bar or Billet

In the area of machining from bar or billet, two work pieces involved profiling and hogout work. These were the rear-spar fitting and the engine mount already discussed in detail. Both might normally be expected to be machined from solid stock for prototype aircraft. The rear spar might be a hogout or a forging in production aircraft, while the engine mount would almost certainly be machined from a forging in production aircraft.

The rear-spar fitting data are distinguished on several counts. We obtained informal estimates from one small and one large shop, fully detailed Laboratory data sheets, and a carefully detailed, step-by-step estimate from a medium-sized shop. The two informal estimates yielded costs substantially below those imputed to the Laboratory's method at any volume. In turn, the Laboratory's make-ready costs were considerably higher than those of the well-detailed costs of the third estimator, but the Laboratory's production costs per unit were enough lower to produce a smaller total cost for as few as 12 pieces. Finally, the two low-cost estimators on the rear-spar job planned to use a poured matrix-metal fixture to hold the work, and one of them based his estimate on the use of a three-spindle milling machine. If it is assumed that these techniques are suitable for an ordinary milling machine, they are also usable on a numerically controlled milling machine. If we make an allowance for these factors and focus our attention on actual per-piece setup and machining times, the Laboratory's experience is clearly superior to all estimates.

For the engine-mount fitting, on the other hand, one small shop indicated that it could substantially reduce the costs realized by the Laboratory. This shop, Company I, estimated that it could produce the engine mount with negligible planning and fixtures. This estimate is difficult to accept, since the engine-mount fitting appears to be the second most complicated machining job of the ten. Except for the connecting-rod die, none of the other nine parts has as many odd angles and shapes with implicit locations. Unfortunately no other estimate for this piece was obtained on a straight hogout basis so it is impossible to compare this company's figure directly with any other.

A composite cost estimate for the engine-mount fitting was constructed by securing estimates for forging die and production costs on this piece. This estimate indicated advantages of the numerically controlled machine for prototype production of a part that ultimately will be forged. The first 33 parts made by the Laboratory were completed in an elapsed time comparable to our estimator's die-production time, yet two engineering changes were incorporated in the program. Four of the eight fixtures would also be used to machine forgings and almost no further programming would be required to delete the finishing operations from the hogout program to make it suitable for forgings.

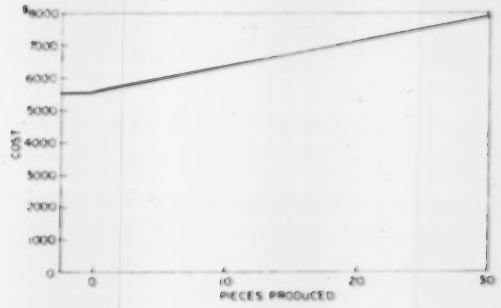

FIG. 6. Engine Mount Fitting Costs Laboratory

The rear-spar fitting was relatively simple to program; but the engine mount, involving unusual combinations of surfaces, was difficult. Also, for both cases, the Laboratory's fixture costs were considerably higher than those estimated by business firms.

Finish Machining

The second job-area, finish machining on castings and forgings, is particularly important, since the numerically controlled milling machine was originally initiated as a complement to the Air Force heavy-forging program, and generally, such work makes up a substantial proportion of all milling machine use.

In this area three parts were studied with the help of six business firms. The most representative part was the aircraft launching socket, which was an aluminum forging. The second was the supersonic nozzle, machined from a mechanite casting; and the third was one of a family of bearing plates cast in aluminum.

Since the nozzle represents a rather extreme case of inappropriate machine-tool assignment, it can be treated with dispatch. The estimator in the job shop furnishing information planned to use a Fischer copying lathe, and furnished us a clear and fully detailed estimate. If we focus only on those cost elements reflected in the Laboratory's operation, the Laboratory had lower make-ready costs, higher per-unit production costs, and total costs lower than this company on a small volume of from one to three nozzles. The case is interesting chiefly as a demonstration that numerical-control techniques can overcome rather extreme unsuitability of a machine tool. It is also supporting evidence for our earlier observation that, given favorable programming and work-holding opportunities, numerical-control methods can win out in the volume range of one piece to a few pieces. It must be remembered, however, that none of the small shops that typically estimated fairly low costs was willing to tackle this job.

The companies estimating the cost of machining the launching socket represent a reasonably good cross-section

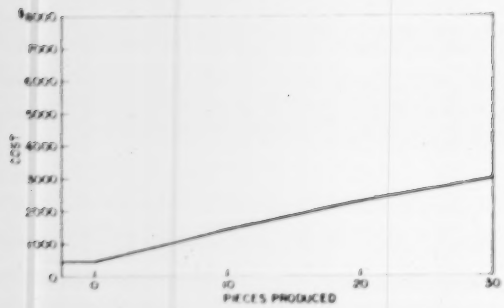

FIG. 7. Engine Mount Fitting Costs Company 1

of New England job-lot contractors. The two smaller shops displayed significant independence in their estimates, with one of them consistently low, the other ordinarily somewhere near the average. The two larger shops both produce machine tools as well as job-lot work and all four shops have had some experience on aircraft work. The estimates submitted varied considerably in the amount of detail furnished and in the degree of formality of attention given to the job, but all were probably fairly representative of the regular estimating practices of the firms supplying them.

Finally, the range of costs resulting from attaching dollar prices to the estimates is strikingly symmetrical, considering the few observations. It has, roughly of course, the same distribution displayed by the aggregate of all the comparisons.

One of the larger shops had both make-ready and per-unit production costs substantially higher than the Laboratory. The low-cost small shop was so much lower than the Laboratory in its make-ready estimate as to raise the question of comparability of work involved. Its unit-production costs were slightly lower than the Laboratory's costs. The other two shops presented the more common relationship of lower make-ready costs but somewhat higher per-unit production costs, so that the Laboratory's total cost function dipped below theirs at some intermediate volume range. The larger of these shops had somewhat lower total estimated costs than the smaller shop, which was not the usual experience; but we should also point out that this larger shop furnished only informal, though reasonably detailed, estimates. Further, this shop gave an alternate estimate on this part which involved higher make-ready cost and lower unit costs based in part on the use of a three-spindle copying miller. This estimate indicated that this company's total costs for larger lots would fall below those of the lowest estimator at about 50 units, and would also be lower than the Laboratory's costs at any volume. Again, however, it should be noted that three-spindle tools are thoroughly compatible with numerical-control techniques. It might be significant to add that this company had, by 1955, gone into a full-fledged numerical control program of its own, delivering its first commercial machine tool with numerical controls early in 1957.

The bearing plate comparisons, using estimates furnished by two medium-sized shops, were quite consistent, in that Laboratory make-ready costs were higher than those estimated by either firm for small or moderate volumes. Numerically controlled milling-machine unit production costs were enough lower than the commercial estimates to produce a total cost cross-over somewhere between 10 and 20 units, and to produce 30 units at a total cost about one-third lower.

The bearing plates were simple to program, and, since they were a family of parts, it is probable that comparisons over the entire lot would favor numerical control even more strongly, because tape preparation for each variant would probably be less costly than the conventional shops' additional costs.

The most objective judgment of the Laboratory's experience in this important area is that its costs are now competitive and that currently developing improvements might well result in clear-cut superiority.

Profiles and Cams

The Laboratory experience shows great promise in the third area, that of cam-cutting, but our conclusions must be somewhat more qualified than they were in the area of castings and forgings described above because the fact that the cams considered were probably not typical of the area as a whole. The two cams studied were mathematically described and both involved a full 360° rise or fall, whereas typically no more than five percent of the cams manufactured would have these characteristics. Though several methods are used to produce cams in industry, conventional production costs probably vary inversely with the amount of dwell specified. While this relationship would also exist if the numerically controlled tool had a rotary table, the costs of cam production on the Laboratory's numerically controlled machine did not vary greatly as a function of degrees of dwell because a Cartesian coordinate system was used.

Two sets of considerations, one favorable to the Laboratory's operation, the other unfavorable, need to be remembered in interpreting the cam-cutting cost comparisons. First, favorable factors include the fact that these cams were numerically defined and thus could be economically programmed. Cooperating companies, however, were forced to allow for a disproportionate amount of computation in contrast to cams specified by graphs or templates of some type. Second, cam production ordinarily involves a large number of tool-locating moves, an area in which numerical techniques excel. Third, cam production generally requires a high level of precision throughout. The generally uniform performance of numerical control, from the start of a tape to its end, is a distinct asset. Problems of metal cutting, tool deflection, and the like, are of course encountered in any method. Finally, cam production is ordinarily demanded in the small-volume range

for which the Laboratory designed its numerical-control techniques.

On the other hand, two-dimensional cams can be produced accurately and efficiently on ordinary copying machines if an accurate master is available. For production of relatively large numbers of identical cams, therefore, many of the above advantages disappear.

With these points in mind, the Laboratory's experience with the CRC and wheel-slide cams is clearly favorable. On the latter cam, the Laboratory's total costs were below those of cooperating companies for quantities well above the usual lot-size demanded. The Laboratory's cost to make the CRC cam matched that of the job shop. In short, the Laboratory using a machine tool that was inefficient for the job produced results close to or superior to those achieved by highly developed, conventional methods.

Private industry has already applied numerical-control techniques to specialized cam-cutting tools. While we have not obtained detailed or documented data on these applications, Laboratory data indicated early in our study that such a move was quite logical. It is perhaps worth noting the fact that the rise in demand for automatic computers and similar equipment has created an induced demand for three-dimensional non-circular, cams and gears. The CRC cam, though three-dimensional in design, was circular. Non-circularity would have affected Laboratory programming costs somewhat, but probably no other elements of cost would have changed greatly. Company cost estimates, however, would probably have gone up substantially in response to non-circularity, since cutting equipment useful for circular cams would no longer serve.

Templates

Laboratory experience indicates favorable opportunities for further application to the fourth area, template manufacture. Many general comments on cam production are applicable here. However, template production is typically better suited than cams to the Laboratory's cartesian coordinate system, so that the only aspect of machine unsuitability displayed here (this was also true for cam production) is in the size of the machine tool used. A small and less expensive milling machine is normally sufficient for cam and template production.

We do not have as many observations on templates as we should like, for we obtained only one useable estimate. This estimate was, however, representative of two others that we discarded because of insufficient detail in, particularly, elapsed-time estimates.

The picture is quite clear, though. Again the Laboratory's total costs were below those of estimating companies for production of a few pieces. Make-ready costs were somewhat higher, due largely to the fact that the Laboratory used a specially designed and constructed fixture, but none of the commercial firms did. The per-unit production cost advantage held by the Laboratory and the numerically controlled milling machine was substantial.

Where more than one template is desired, numerically controlled production may well be economical at present, since template specifications will ordinarily require hand finishing of each unit produced by conventional methods. The aircraft-propeller template studies is a testing device manufactured in moderate volumes. Should subsequent developments in programming and work-holding show numerical-control methods to be competitive with conventional methods in the production of single units of this type, the demand for numerically controlled equipment and related personnel would be greatly increased, because a substantial proportion of the demand for templates is in the low, say one-to-five, volume range.

Miscellaneous Jobs

In addition to the work-areas summarized above, we studied two jobs that did not fit neatly into any of those categories.

The first of these is die-sinking for the connecting-rod die-blocks. Two thoroughly experienced shops furnished data on this operation based on their actual cost information. In spite of the fact that two aspects of the job were favorable to Laboratory techniques, the end results of the comparison were unfavorable.

There were two favorable points. First, the symmetry of the die cavities made it necessary to program only one quarter of the total metal-removing operation with the other three fourths cut by rerunning the single tape with director signs reversed. Second, ordinary die sinking requires continuous machinist scrutiny of the cavity, so that air cooling, rather than liquid, is necessary, and metal removal is consequently relatively slow.

On the other hand, the contours of the cavities were not explicitly defined and involved several intersecting surfaces. Both of these characteristics result in high programming costs.

In spite of the favorable aspects of the job, Laboratory programming and tape-preparation costs were enormously greater than the modest template and lay-out costs for commercial machine shops. While numerically controlled metal-cutting time was roughly one-half that of the two die-sinking firms, our costing procedure results in almost identical costs for this phase of the operation. Consequently, the high program and tape-preparation costs are recovered only for relatively large numbers of die sets. This relationship would be markedly different for dies that require models or masters for conventional production instead of the simple templates required in this case.

This case illustrates one important aspect of numerical control, namely that the costs are not dependent upon the accuracy of the work produced. Thus, since the forging produced by these dies will be rough and finish-machined all over, die accuracy is not of first importance and the dies may be produced with simple layout and templates. There is, however, no significant difference in programming for numerical control if the tolerance is .050 inch or 0.005 inch. Thus while cost of conventional dies would in-

crease sharply if greater accuracy were required, numerical control is already almost as accurate as possible on the present machine tool, and the additional accuracy could be obtained with little increase in cost.

The second job in the miscellaneous category was the printed circuit board. It proved favorable for numerical-control procedures in spite of the fact that Laboratory personnel failed to take advantage of an opportunity for efficient programming and work-holding.

The circuit board comparisons are interesting for two reasons. First, the Laboratory operation was outstandingly more economical than those of estimating companies. Second, this problem, like the bearing plate discussed briefly above, involved a family of different but closely related work-pieces. The costs we allocated to the numerically controlled operations were based on the assumption that only one board was produced, since we limited our investigations to a single board. However, a "library" of tapes was developed covering operations repeated frequently within the family, and the fixture used was suited to all boards produced, so some insight was gained in the economies to be expected from numerically controlled techniques in a fairly common industrial situation. The flexibility of numerical-control programming would appear to be a valuable asset in firms producing similar families of parts, each member of which varies from the others in one or more dimensions. The paper tapes, which serve the same function as complicated templates and models, are easy and inexpensive to splice, duplicate or modify, store, and ship.

The favorable cost comparisons on the circuit board also illustrate nicely the value of numerical-control techniques in the production of pieces that require numerous tool relocations. Discontinuous operations, in which the tool does not work between stations on the work-piece, appear to be a particularly fruitful area for exploration. A large New England machine tool maker has, since this study, developed a numerical control system for its precision jig borers and hole grinders.

Summary

To summarize this section on work-classifications, we note that the ability of the Laboratory's numerically controlled milling machine to compete with established shops using a variety of tools in a wide range of metal-cutting areas is most impressive. Since all parts were designed for conventional methods, this is a remarkable accomplishment. Even those cost studies least favorable to the Laboratory operation showed numerically controlled metal-cutting to be faster than conventional, but the studies emphasize the need for further improvements in make-ready operations. A substantial reduction in make-ready costs might be expected to result simply from integration of numerical-control techniques into the overall industrial fabric.

A rather surprising result of this study was the spread of the present-cost data. Figures 8 and 9 indicate the range of data obtained. Figure 8 summarizes the total make-ready and machining costs for production of a single piece. The total make-ready and machining costs for the Servomechanisms Laboratory are treated as 100 for each piece (regardless of the dollar amounts actually concerned) with the cost estimates for cooperating companies converted to percentages of the Laboratory's costs. This puts the costs for each workpiece in comparable terms, but comparison between various workpieces is not meaningful.

Figure 9 shows the cost of machining 30 of each workpiece. Again, the costs for each piece are converted to relatives with the Laboratory's cost for each piece equal to 100 percent.

An important fact brought out in Figure 8 and 9 is that the Laboratory's costs lie high in the range of estimates. Analysis developed the fact that programming and tooling are chiefly responsible for the relatively high total costs of the Laboratory's work.

Among the conclusions that may be drawn from this study are:

1. It is possible for a contract manufacturing facility to exist and continue to do business, at present, in the midst of competitors who can at least estimate work at much lower costs.
2. The new technique of numerical control, as practiced by the personnel of the Servomechanisms Laboratory using an experimental machine, permits work to be done at costs which lie within the range of costs estimated by firms practicing presently established techniques.
3. If the Laboratory group had been able to carry out tool design and manufacture as economically as the cooperating companies estimated that they could, the Laboratory total costs would have fallen more nearly at the center of the range of estimates.
4. Any appreciable improvement in programming and tape preparation techniques will render numerical control clearly economical even without improvement in the machine tool equipment. Conversely, any system requiring more costly programming procedures would seriously reduce the range of jobs which can be performed economically.

These conclusions should not, however, be accepted without reservation. They are based upon a small and uncertain sample operation, in which it has been impossible even to estimate most of the uncertainties. However, our initial question, relating to the economic feasibility of adoption of numerical control techniques by aircraft makers, can be given a qualified "yes." It is not clear whether this reply should also be given to less-specialized machine-tool users.

General Evaluation of the Study

It was stated earlier that in comparing production methods the effect of the new technique on revenue would not be considered. Within the framework of this limitation, it should be possible to draw one of the following three conclusions:

1. Cost savings of numerical control are large enough to warrant scrapping existing equipment immediately, and replacing it with numerically controlled tools.
2. Cost savings of numerical control are not enough to warrant

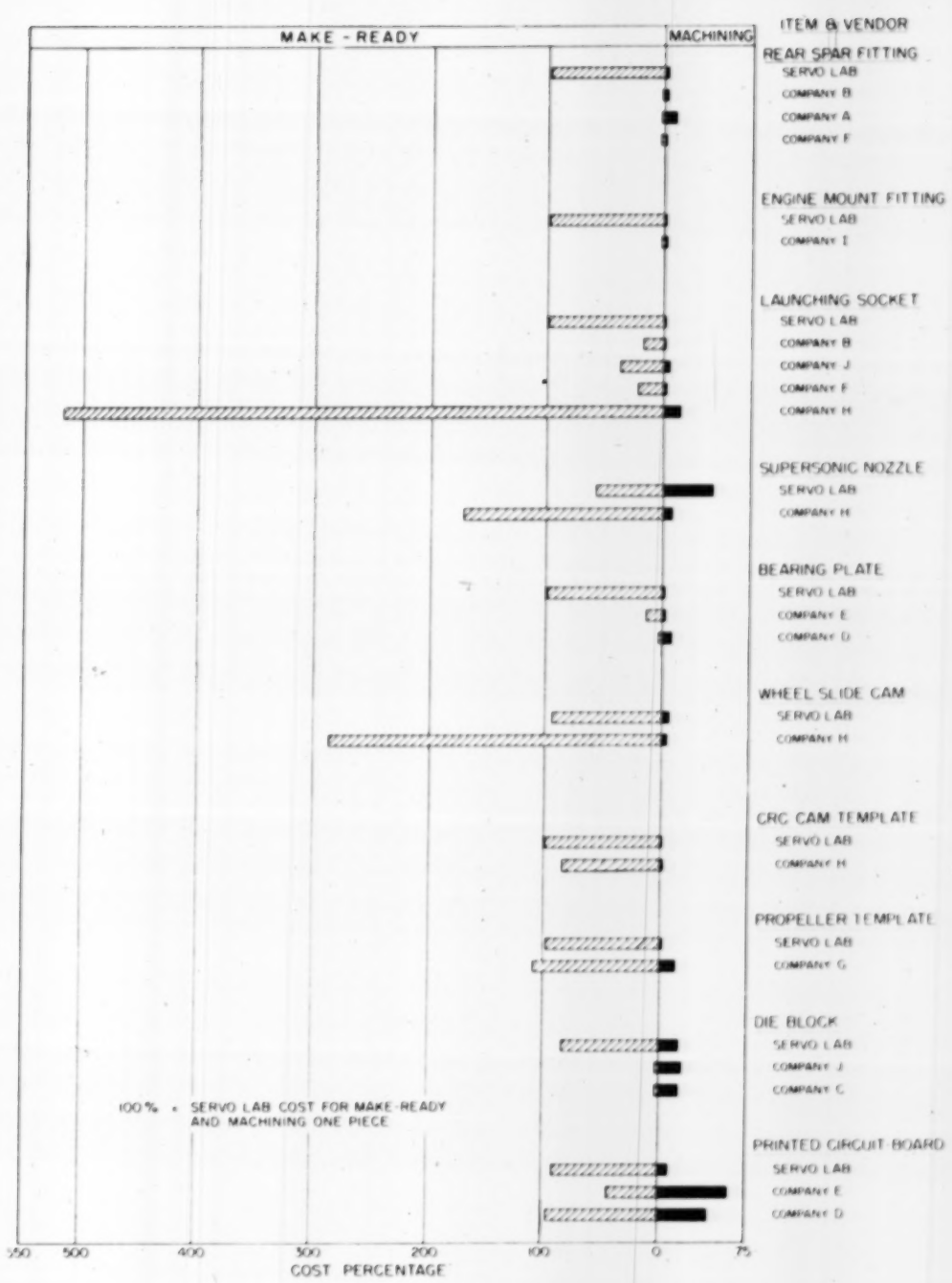

FIG. 8. Single Piece Production Comparison

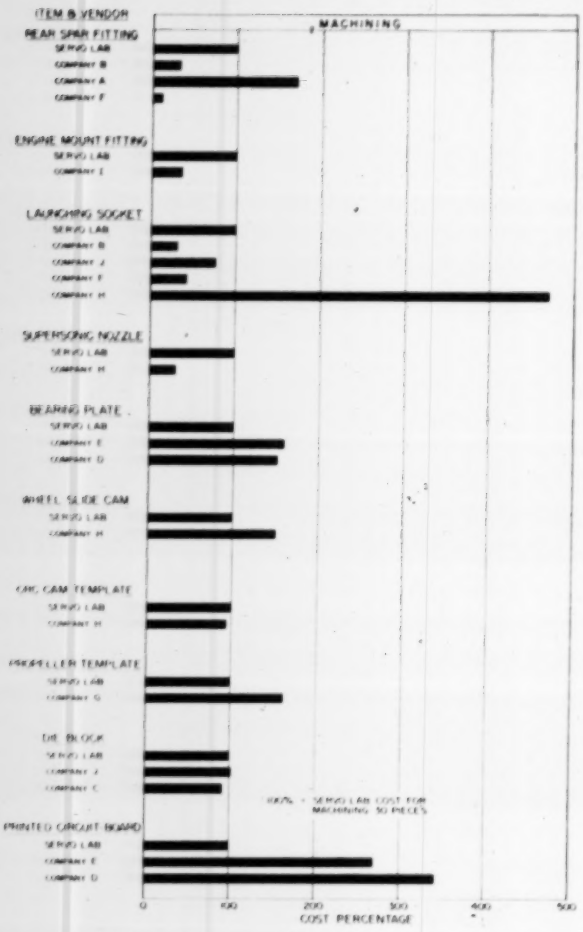

FIG. 9. Thirty Piece Production Comparison

immediate replacement, but warrant purchase for expansion and normal replacement purposes.

3. Use of numerically controlled tools does not afford any cost savings.

Basis of Comparison

Whether cost savings warrant immediate adoption is the most severe test that any new method or tool faces. For an affirmative answer to this question, total revenue minus total cost with the new method must be greater than total revenue minus out-of-pocket costs with the old.

Most potential users would have to determine conclusion 1., for themselves, on the basis of detailed, highly specific analyses. We believe, however, that our study can lead to a general choice between conclusions 2. and 3., after some consideration of our study methods, data-gathering techniques, and evaluative decisions.

Pricing the Estimates

If numerical-control metal-cutting techniques were closer to conventional techniques, it might not be necessary to show costs in terms of dollars for the cases selected for study. That is, if our studies required only comparisons of two rather different methods using different quantities of similar inputs, the study could be done in terms of the familiar labor and machine-time evaluations often used by Industrial Engineers. Dollar costs would probably be used to determine the outcome of the comparisons, but it would not be necessary to price the numerous inputs that were identical for both methods. However, the numerical-control production technique differs from conventional metal-working processes at every step from design through inspection.[3]

This radical difference made it necessary to secure cost estimates that were fully detailed and carried through the same range of the production processes by both techniques. In general, we were able to obtain such information. However, it was necessary to price physically non-comparable inputs and express the costs for each method in dollars as a common denominator.

Despite this need for dollar prices, our main effort to secure precision was restricted to acquisition of technical details. Capital costs (control-equipment construction and installation costs, development expenses, and learning times), labor skill requirements, and prices involve substantial areas of guess-work. Our "average rate" of $5 per hour for the operations estimated by the job shops cooperating in our study seems to reflect fairly accurately the costs of operators and machines of the types discussed here. The same rate was also used for skilled operations not directly involving machines (designing, calculating and inspecting).

In a similar fashion, for numerical-control techniques, we have used a flat figure of $5 per hour to cover labor and related costs, and a separate charge of $5 per hour for numerical-control-equipment amortization and related operating costs. We did not try to reflect more precise figures, because further refinements in pricing would represent purely illusory precision. We felt, for instance, that an early adopter of numerical-control techniques might find it necessary to assign more skilled operating labor than Laboratory experience has shown to be necessary. Ultimately it would probably be possible to reduce skills assigned, but neither we, nor labor economists we consulted, are prepared to guess how long this might take.

Also, as we have noted, there are large geographical variations in labor rates and practices which are best handled for our purpose by averaging methods.

Analysis of the Cost Comparisons

In analyzing the data collected, it must be remembered that there is no single suitable definition of business cost, but that cost classifications must be tailored to analytical purposes. With this principle in mind, we propose to examine our cost studies in more detail.

[3] For an interesting experiment in collecting comparative estimates from metal working shops, see *Automatic Machining*, June 1957, pp. 56 ff.

First, it will be noted that the usual theoretical economic cost curve assumes the existence of an optimum process. Thus, for any selected output of a given product, a combination of inputs which will display the least cost is chosen ("production function"). The specific process and material inputs used will be economically equal to or superior to all possible alternatives. That combination will be chosen which is most efficient at the desired output, taking account of both physical input-output coefficients and expected price relationships.

In practice, however, these conditions will be only approximated at best. And, more important for this study, the most efficient combination can usually be achieved only over a long time by accumulating experimental knowledge of technical alternatives, substitution relationships, and price behavior. Obviously, numerical-control techniques are too new to allow us to anticipate an optimal, technical balance among the numerous and complex variables associated with even relatively simple jobs. On the other hand, the conventional techniques on which our estimates are based are the result of long periods of trial and error, and cumulative development. Despite this long development period, few firms can be expected to be familiar with all relevant alternative methods for producing a particular work piece that they have not actually produced

Similarly, many variables associated with conventional job-shop production methods can be priced in terms of well-established and fairly well-defined markets, although there is ample evidence that price estimates tend to be made in a somewhat perfunctory manner. The corresponding input variables for a numerical-control production system, on the other hand, include a substantial number of elements for which no market prices have been established. It is not possible to secure adequate estimates of future supply of and demand for such technical personnel as programmers or methods planners, or for the equipment installed and in operating condition. Our cost-value findings are, at best, only indicative of the rigorously defined cost functions found in economic theory.

A second deviation from the economist's "production function" is our assumption that, for a given production technique, total costs are directly proportional to the volume produced. Consequently, we have assumed that all cost estimates can be adequately graphed in relation to volume by means of straight lines.

The characteristics of numerical controlled machine tools are in fact likely to result in a linear cost-volume relationship. The probable linearity results from the fact that every piece in a given production lot is produced by rerunning one or more tapes. Numerical-control production techniques may allow some process modification as a function of volume largely by means of fixture design and materials handling, but little experience is available on this point. Actual machining times would presumably not be substantially different over any relevant volume range, because essentially the same methods would be employed.

However, by virtue of the flexibility of current production methods, conventional shop practices are more likely to display curvilinear cost functions. It is ordinarily both feasible and desirable to change production methods, and often materials and the product itself, in response to variations in the desired volume of output. The data that we collected from estimating shops reflect substantial changes in production methods on several jobs as "lot size" was increased. We show these types of estimates as separate cost functions because of the substantial differences in fixed and variable cost elements ordinarily involved.

It is necessary in any empirical investigation to assign confidence limits to the relationships developed. While we are not in a position to do this in a rigorous statistical fashion, we can at least note that on this count, data obtained from the Servomechanisms Laboratory are somewhat closer to the theoretical model than are cost figures developed from cooperating company estimates because the Laboratory actually made the pieces and kept reasonably detailed and systematic records of man and machine times. Cost estimates, on the other hand, inevitably contain some uncertainty. In most cases the estimators were to some extent familiar with a wide range of alternative methods, although some alternatives were not real, because suitable equipment was not available. Also, different shops tended to evaluate differently the efficiency of a given method. Metal-working theory is distinguished by substantial gaps and many areas of controversy.

In other words, the Laboratory's costs were based on actual experience with products, whereas in only two instances was satisfactory data obtained from an outside firm that had actually produced a piece selected for study. Further, we found no shops that had made any substantial attempt to record and evaluate the accuracy of their past estimates. We concluded that it was best to present all estimates, with as much detail as practical about the circumstances under which they were gathered, in order to permit readers to try to evaluate their probable accuracy.

Servomechanisms Laboratory Data

Data on Laboratory operations were gathered from two types of records. First, a series of job-analysis memoranda prepared after the job by the programmer in charge and, second, the daily machine-tool log sheets kept by the machine operator.

These data were compiled by individuals working in an educational and scientific atmosphere. They were spot checked and appeared to represent accurately the actual total time spent on each job, including the normal non-productive time of each individual. In most of the ten jobs studied here, the actual time recorded was considerably in excess of that estimated for the job before it was undertaken. These figures, therefore, actually include all hidden costs often overlooked in preparing job estimates.

The experience records, while reasonably accurate, reflect to an entirely unknown extent many factors severely disturbing to the objectives of this study. For example, during much of the period covered by these data, the engineering group was expanding. In order to familiarize new personnel with the system, each engineer's first assignment was the programming of a workpiece. No quantitative data were available to indicate the effect of this policy on the indicated costs. Again, no attempt was made to insulate the operating personnel from a continuous stream of visitors or to prevent a special demonstration from disrupting the production operation whenever the occasion appeared to warrant. Thus, while it is obvious that the broader, educational objectives of the Laboratory often took precedence over the specific objective of obtaining efficient production for comparative cost purposes, no allowance has been made, since the effect cannot be measured.

A paramount problem arose from the fact that many pieces machined by the Laboratory were substantially more intricate than the average work done by milling machines.

Furthermore, the variety of jobs machined was so great and the runs so short that insufficient experience was obtained with a particular type of work to gain appreciably from such experience. Many jobs were unique, so that the skill developed by the Laboratory staff was not directly transferable to other jobs.

Some Laboratory jobs consisted of enough similar parts (for example, a set of templates each varying slightly from the other) to constitute a family that enabled personnel to make good use of its skills on successive parts, but too much of the planning and programming work was at the low-experience, high-cost end of the learning curve. Continued operation would probably have enabled the Laboratory to draw upon its body of planning and programming experience in much the same way that any organization does as a technique becomes well established. A company utilizing numerical-control techniques would probably need to develop policies concerning types of work to be done in order to develop skills in certain areas.

The Laboratory is part of a non-profit organization, and its motives and the motivations of its staff do not always lead to lowest costs for either its operations, in general, or processing pieces by numerical control, in particular. Effective research is considered far more important than minimum-cost production.

The Laboratory has a limited machine shop so that, in some cases, it used its milling machine to perform operations that might have been done better on other equipment. Similarly, jigs and fixtures were often manufactured on second-best machines and at higher costs than for a well-equipped shop.

Outside-Shop Data

In some job studies, it was difficult to obtain strict comparability between operations estimated by cooperating companies and those performed by Servomechanisms Laboratory. Ideally, identical results in machined pieces would serve much better than similar operations in machining for developing economically comparable data. Regrettably, there were several causes of non-comparability. First, cooperating companies often started with earlier operations (or continued with later operations) than those covered by Servomechanisms Laboratory data, because the Laboratory was primarily interested in the numerical-control phase and tended to de-emphasize some of the initial and subsequent operations or had them performed elsewhere. Second, materials actually available to the Laboratory and assumed to be available to cooperating companies were different in some cases (for example, the supersonic nozzle was cast in two halves for the Laboratory to mill, but Company H assumed that it was cast in one piece for turning on a lathe), so that substantial differences in required operations arose (in this case, the Laboratory's production method required brazing the two halves together). Third, in some cases the Laboratory did not inspect and gage its work as carefully as some cooperating companies planned to do, but left these tasks to the person or company for whom the demonstration piece was cut. However, in other cases, the Laboratory gaged some pieces (notably templates) more carefully than was physically or economically possible by conventional techniques. Fourth, the surface finish produced by servo-actuated cutting tools differs in appearance from that obtained by other methods, and it was not possible to place an economic value on this difference.

Another source of uncertainty in our data obtained from conventional machine shops was our inability to convey to them the precise nature of the information we wanted for comparison with data generated in the Laboratory. There were numerous reasons for this—some institutional, some communicational.

Conventional machine shops are accustomed to obtaining specifications in ways that are rather narrowly defined for any particular type of job. Specifications expressed in other forms may result in substantial additional effort to convert from the unfamiliar to the familiar form or, in some cases, complete refusal to deal with unfamiliar specifications.

Our experience indicated that the size of a machine shop had some bearing on the care used in estimating. Larger shops tended to make more elaborate analyses of materials, tolerances, and specifications for a job than did small shops. This additional care apparently resulted because larger shops had an estimating department with specialized and experienced personnel, well established routines, and formalized reporting procedures. Small shops, on the other hand, were likely to have only one estimator who might spend much of his time at other assignments, have informal routines, and furnish reports in a poorly organized manner.

Although our information was not sufficient to document the point, we have the feeling that, for identical jobs,

larger shops quoted substantially higher man-and-machine cost estimates to us than did small shops. There is an industry-wide belief, which we were not in a position to check, that small companies are willing to quote a low price to obtain an order with the expectation that the price can be renegotiated upward.

Larger shops with more facilities should, if specialization counts for anything, be able to do work at less cost than small shops. The estimates that we obtained do not, however, bear this out. The man-machine cost estimates of larger shops having many special-purpose tools seemed to be higher than the small shops with few machines and almost no special purpose tools.

There were indications that large companies have a downward bias in any informal estimates furnished by management that is proportional to the number of managerial layers between the person closely associated with the operation (machine operator, process engineer, or estimator) and the person reporting (president, vice president, or superintendent). Apparently, the farther a person is from a task, the less likely he is to remember the difficulties, mistakes, and other factors contributing to high costs.

To a far greater extent than we would have judged possible before undertaking our field work, it appeared feasible for high-cost producers to earn a profit over a considerable period of time in the job-lot metal-working industries. This situation reflected in part the relative importance of such non-monetized variables as probability of compliance with delivery, technical competence, and reputation among buyers. It also reflected imperfect knowledge and faulty communications in what is, after all, an enormously complex "market" that is highly segmentized with respect to experience, reputation, geography, adequacy of available equipment, and rates of technological advance.

Further, the firms in this manufacturing area, and even more the machine-tool producers among them, have continually faced heavy cyclical swings in their volume that are far more pronounced than those affecting business at large as a result of the accelerator effect. A slight increase in the demand for consumer products is capable of producing a large increase, percentage-wise, in the demand for subcontractors' services, and an even larger rise in demand for machine tools and other basic capacity factors. A slight drop in the rate of increase of consumer purchases, conversely, can produce a large reduction in basic market activity.

Under these conditions, even a highly inefficient operator can get profitable business on a sellers' market where the lowcost firms are operating at full capacity with substantial backlogs of orders. The gist of these observations is that, in a market of this kind, there is an excellent chance that one firm or more, in each geographical area providing a substantial volume of metal-working contract work, could operate profitably utilizing the Laboratory's numerically controlled milling machine as it stood in 1954 without any technical alterations, but with, probably, some improvement in the make-ready costs of programming, tape preparation, and fixture design and construction. The key to such profitable operation, however, would not be costs and prices lower than those currently prevailing, because there are no such "prevailing" prices in this market. Profitable operation would turn largely on the firm's ability to find an adequate volume of work at prices exceeding full costs during periods of relatively high demand.

Given successful solutions to the problems which accounted for high Servomechanisms Laboratory costs, plus the availability of relatively standardized commercial models of numerically controlled tools, a much stronger conclusion could be supported.

Future Developments

The numerical control cost studies show a consistent pattern of high make-ready costs and normal to low production costs. Make-ready costs include:

1. Fixture design and production, consistently higher in the Laboratory than in outside shops.
2. Programming.
3. Tape preparation.

We can safely neglect fixture costs, since fixtures are no more intricate, and may be less intricate, when numerical control is used. If outside shops are able to design and build fixtures more economically than the Laboratory now, their economies will apply directly to numerically controlled tools when used by industry.

The other costs, however, deserve some attention. The parts used in this study were programmed by hand with the exception of the supersonic nozzle, which was done by hand and by high-speed computer, and the wheel-slide cam, for which the data were calculated by computer and the tape was punched by hand. It is possible to automatize portions of these operations by using automatic computers, and by modifications in the design of the equipment.

First, approximately half of the tape-preparation time can be eliminated by using a more efficient tape code than that used by the M.I.T. Air Force milling machine. This saving has already been demonstrated in a prototype director-system developed under private sponsorship at the Laboratory and now in commercial operation.

Second, automatic digital computers can perform the computations necessary to obtain the tool-center loci. When used for this step, they can punch the machine-control tape directly.

Some significant work to reduce data preparation costs, done at the Laboratory parallel to and following our initial study, dealt with the problems of programming and tape preparation.

The use of digital computers at M.I.T. and elsewhere for preparing control data for the milling machine was studied and reported by Runyon (1). Program sub-routines for essentially automatic computation of control data for

cutting circles, cams, a plane spiral, a template, a surface of revolution, and cones were developed for Whirlwind I (a large scale electronic digital built at M.I.T.).

Runyon found the break-even point in automatic compared to manual data preparation depended on the particular job, method of presenting its dimensions, and availability of computer routines and sub-routines. Automatic data preparation, measured in terms of number of tool center points computed, was considered more economical under the following conditions:

1. More than ten points, if a routine for a similar job were available.
2. More than 100 points, if a new routine was required assuming sub routines available for most steps and convenient presentation of dimensions.
3. More than 1000 points for anything, except composite curves and surfaces, involving wholly new programs.

Runyon also surveyed the ability of commercial computing services for preparing machine control tapes for the supersonic nozzle (see Figure 2) and air foil templates. Prices quoted by four services for data preparation for the nozzle ranged from $100 to $2,200. After completing the work involved, for the nozzle, three of the four computing services quoted prices ranging from $500 to $7,725 for airfoil templates. Runyon's procedure for obtaining data differed from ours for he actually tested price quotations by having computing services prepare machine control tapes. Numerous difficulties that arose in making satisfactory tapes reflected complexities of the parts, methods for specifying dimensions, and the Laboratory's unique representation of numbers (nicknamed "Chinese Octal" in the Laboratory) on punched paper tape to control the milling machine.

Runyon's suggestions (Chapter VII) for extending his study touched on metal cutting geometry; numerical methods; subroutine libraries; and suitability, application and economies of general purpose computers for preparing control data for machine tools.

Siegel continued to work on the problem of more effective utilization of digital computers to reduce tape preparation costs (2). Siegel developed a processing routine to transform the Whirlwind I computer (but adaptable to other large scale digital computers) into a special machine with characteristics designed specifically for machine tool programming. The input language to describe machine instructions, based on ordinary English and mathematical notations, is far simpler than the intricate instructions associated with digital computers. The output is punched paper tape suitable for use in the milling machine. Logical and numerical procedures involved in the program to convert input information take place automatically so that little or no training in digital computation is required for use of Siegel's system.

Limited use of the experimental version of the processing program developed by Siegel indicated that people skilled in numerical control could easily learn the input language and its connections in less than an hour. Correct input tapes have been produced on the first try despite complexities of the parts. Programming time for one piece was reduced from eight hours by manual methods to less than fifteen minutes for the processing routine. Computer time was less than a minute, exclusive of initial read-in of the processing program. There are indications that Runyon's and especially, Siegel's techniques for computer processing specifications of parts to prepare control data tapes will be adopted by industry.

In summary, it appears that the immediate future will bring substantial reduction in those areas that this study showed were the most costly. In addition, those types of cost-reduction that are better handled in industry are now presumably being effected, since numerical control techniques are now in limited but promising production use.

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Industrial Engineering's Role in America's Future*

By C. Lloyd Thorpe

Employee Development Manager, Guy F. Atkinson Company, San Francisco, California

The years immediately ahead are crucial, and there is no mistake about it. To gain prospective for this discussion, let us review the highlights of some of the major economic and social factors that will determine the warp and woof of America's cultural fabric-to-be, particularly those that will significantly influence the environment wherein Industrial Engineering will be required to make its unique contribution. As I see it, at least six of these should be underscored (there are others, of course). Here they are:

1. The ominous clouds that are hanging over our civilization.
2. Society's evolving dominant role in the power structure.
3. The employees' changing status and needs.
4. Society's increasing demands upon business and its management.
5. The vulnerability of industry and its leadership.
6. The relatively recent emergence of management as a profession.

All of these, I submit, though emanating from widely different sources, will soon synthesize in a way that will focus on industrial and business management and will test them to the limit. I further submit that the fate of western civilization as we know it may well be riding on the way the manager operates as the impacts of these pressures converge. And finally, I submit, the Industrial Engineering function can be a strong right arm for management in those critical times and might indeed "make the difference", but this will be the case only if the Industrial Engineer has built his personal foundations solidly as a necessary base for a sound professional super-structure.

Let us discuss each one of these six points briefly as background to develop this premise:

Ominous Clouds

There are indeed ominous clouds hanging over our civilization. It is far more than just an academic matter. Serious students of the world scene are distinctly disturbed over the trends that are developing. For example, Albert Schweitzer, properly designated "this century's greatest citizen", has this to say:

> We are living today under the sign of the collapse of civilization. . . . What yet remains of it is no longer safe . . . (11, p. 1-2)

> The history of our time is characterized by a lack of reason which has no parallel in the past . . . There is today only one explanation, viz., that we sought to live and to carry on a civilization which has no ethical principle behind it (11, p. 37).

Or listen to Elton Trueblood, one of our top-grade social philosophers:

> The sober truth is that, as a people, we do not believe we are engaged in a race with catastrophe. We are not aware of the dangers we face, and consequently we are doing relatively little to meet them. If we could put the same keen intelligence and careful judgment into the revival of faith and the discovery of the proper objects of faith that we now put into the production of magnificent machines, man's life on this earth might come into a new and glorious day. We fail to do this because we do not read the signs of the times or listen to our prophets (12, p. 19).

Pope Pius XII in his 1957 Easter message said the following:

> Evil habits in every form have reached such degrees of precocity, impudence and universality as to arouse serious misgivings in those who have at heart the destinies of the world.
>
> The human race seems like a body . . . in which the blood circulates with great difficulty, since individuals, classes and peoples persist in remaining divided and subsequently without social intercourse.
>
> When they do not ignore each other they hate each other, plot against, struggle with and destroy each other (14).

Let us conclude this all-too-brief treatment — wherein we have omitted any reference to communism simply because it is viewed here as more effect than cause — by this statement by Trueblood:

> When we say that the most urgent problem of our time is the spiritual problem we are opposing directly the popular opinion. Most people do not believe it (12, p. 17).

Society's Role

In the western world, perhaps the most significant occurrence in the last two centuries has been the emergence of the so-called "common man" as a dominant force. While we sometimes tend to overlook this meaningful fact, comparison of the past with the present makes it quite clear.

The beginning of the industrial revolution occurred in

* Based upon a presentation to the Portland Chapter of AIIE at their charter night meeting on May 23, 1957.

the latter part of the 18th century. At that time feudalism was the dominant social organization and a master-servant relationship existed. People, as such, had little power and had relatively little social worth except as they fulfilled the somewhat insignificant roles that destiny had thus far assigned them. While some social philosophers and many religions had called out for reforms, these were heard as voices crying in the wilderness. Such things as declarations of independence and of the rights of man, of bills of rights, and the like were being discussed but had not reached the hour of decision. In fact, almost a hundred years would have to pass before America would rid itself of slavery.

Contrasting that situation with the present, so far as the social evolution of people as persons is concerned, we can readily recognize that startling progress has been made.

Employee Status

Another evolution that probably is a corollary of the previous point concerns the status of the employee as such. Again referring to the industrial revolution, we have indicated that people weren't worth much at that time. I should stress that this was a fact due to the culture of the time and was not due to anything inherent in the industrial system. At the start of the development of the factory system, people as employees assumed the only role their society could adjust to; that is, they were in a quasi-feudalism such that the factory owner was similar to the feudal lord and the workers were like serfs. Of course this has long since disappeared, but the scars of the old wounds inflicted during the earlier conflict periods are still close enough to the surface to cause pain when the going gets tough.

This evolution has resulted in the emergence of people from being just unidentified masses to being dignified as individuals. The upward climb has given us a new social base with a consequent realignment of forces so that we now contemplate the middle class — whatever that is — as being composed, in part, of industrial employees. These employees are now vastly better educated and informed; they have achieved a measure of unparalleled economic security, of maturity, and of sophistication. And, in the western culture at least, they are undergirded by a political freedom that, in the final analysis, makes them in fact ultimate controllers of the situation. In this great emancipation of the "common man", it is not conceivable that he will tolerate the social irresponsibility of industrial organizations that cannot or will not face the facts of life concerning the changing status of the individual who happens to be an employee.

Peter Drucker puts it this way:

> Man must have status and function in his society in order to be a person . . . But the group's own cohesion and survival also depends on the individual's status and function; without it the group is a mere herd, never a society. And only a society that gives status and function to its members can expect their allegiance. Status and function of the individual members are the requirements of individual and social life. They are verified by all historical experience (3, p. 151-152).

And O. A. Ohmann of Standard Oil Company of Ohio adds this:

> Our goals in business have been too materialistic. For most people, the job is the center of life and should be the source of many of its greatest satisfactions. We are learning (only gradually) that high pay, shorter hours, and greater fringe benefits are not the answer. There is a hunger for something worth living for, a search for meaning and social significance, and a desire for self-expressive service. These goals will not be satisfied by more bathtubs, deep freezes, T.V. sets, or automobiles (7).

Increasing Demands

That an increasingly enlightened society is placing increasing responsibility on industry is apparent. The whole field of public relations is one evidence of management's awareness of "the public's" new status. The plight of chemical plants and stream pollution, of smog and contemplated legislation regarding it are pertinent examples of this.

But the problem is far deeper than that and a public relations department cannot cope successfully with the more profound implications of it. An observer of the current scene — who happens to be an European industrialist — has stated recently:

> Man never desires *strongly* anything except that which he believes to be immediately available, either to him or to his direct descendants. That is why, parallel to the acceleration of technical progress, an immense desire for greater material well being has violently got hold of the whole of humanity — of those who truly were suffering from hunger, cold, the sicknesses of malnutrition and of ignorances, as well as of those who already enjoyed a minimum necessary to their physical and intellectual flowering. All these people began to desire avidly the superfluous which, tomorrow, will be within their grasp. . . (6, p. 20).

This may be quite obvious but the implications of it might not be as clear. Let us pause a moment and consider. If society has built up this great desire for things and if it is denied them by (as it may assume) industrial management and its staff who can't produce in terms of this demand, what then? Peter Drucker provides an answer and it isn't reassuring:

> Historically, society has always refused to allow such permanent concentrations of power, at least in private hands, and certainly for economic purposes. However, without this concentration of power which is the modern enterprise, an industrial society cannot possibly exist. Hence society has been forced to grant to the enterprise what it has always been most reluctant to grant . . .
>
> This, however, imposes upon the business and its managers a responsibility which not only goes far beyond any traditional responsibility of private property but is altogether different. It can no longer be based on the assumption that the self interest of the owner of property will lead to the public good, or that self-interest and public good can be kept apart and considered to have

nothing to do with each other. On the contrary, it requires of the manager that he assume responsibility for the public good, that he subordinate his actions to an ethical standard of conduct, and that he restrain his self-interest and his authority wherever their exercise would infringe upon the commonweal and upon the freedom of the individual (4, p. 382-3).

He also points out:

This responsibility is absolute and cannot be abdicated. No management can be relieved of it. Managements are in the habit of saying that they have a responsibility to the shareholder for profits. But the shareholder, at least in a publicly owned company, can always sell his stock. Society, however, is stuck with the enterprise. It has to take the loss if the enterprise does not produce adequate profits, has to take the impoverishment if the enterprise does not succeed in innovation and growth.

For the same reason management has a public responsibility to make sure of tommorrow's management without which the resources would be mismanaged, would lose their wealth producing capacity and would finally be destroyed (4, p. 387).

Vulnerability of Industry

Well, what about the future? What are the problems that make industrial management vulnerable? In our limited amount of time here let us consider just this business of meeting production and social needs. The problems will be very real. It has been estimated that within the next 20 years the following events will occur in America:

1. Total population will increase by at least two fifths (2, p. 181).
2. But working age population will increase less than one third (2, p. 181).
3. Therefore, substantially greater productivity will be required just to keep even; anything less could result in ruinous inflation.
4. By these statistics it seems likely that the critical scarcity of employable persons will probably get worse.
5. Not only that, but the increasing improvements of the standard of living as demanded by society, including industrial employees, will exert a substantial pressure on management to produce the things persons will want to buy and will be able to buy. The public has long accepted remarkable production records as par for the course. Industry will be required to "come through" again and again and anything less than success will be quite unacceptable. And a sober thought is that a lot of persons - a majority of them, but not all, are behind the Iron Curtain - are betting it can't be done.
6. Concurrently, employees will be demanding more leisure time, which is to say shorter hours, and the power of their organized strength, coupled with their relative immaturity in economics, will contribute to the heavy inflationary pressure that will be present in increased amounts. (At least, the pressure will be inflationary unless we attain a productivity improvement at a rate not previously reached, not presently predictable.)

But employees will not be content solely with economic gain. The evolution of our social order to date gives us every indication that the employee will exert pressure to obtain the "good life" within the work situation as well as outside it. As has been stated before, as a general rule people do not aggressively seek the unobtainable; however, there is the bloody evidence of history to support the point that the reverse is also true.

Management as a Profession

This leads to the final point of the six which considers the fact that management has emerged so recently as a profession. The so-called "father of scientific management", Frederick W. Taylor, did not begin his pioneering work in this field until the 1880's and any kind of general acceptance of management as a profession did not occur until well after the turn of this century.

Management has thus been required to evolve during the last fifty years, while the stability of this period has been upset by two world wars, a depression in the 20's, a worse one in the 30's, a Korean and a continuing cold war. During this same period of time we have witnessed the transfer of the administration of business from the owners to the professional managers, and ownership itself has become widely dispersed with the rise of the corporations and the distribution of stock shares.

Out of this has come a management that is rapidly maturing. Such words as human relations - or even more significant ones such as morals, ethics, and the like - are getting into the vocabulary and practice of responsible business men and women on an increasing scale. They are as tools to be used rather than platitudes to be uttered.

Things are indeed on the move. That this can be demonstrated by the hard fact of payoff, and thus is not only altruistic but also realistic, is well illustrated by this statement of Ralph Cordiner, President of General Electric Company:

If we were forced to rely entirely on conventional methods of increasing productivity, I would be inclined to regard this goal (of increasing General Electric productivity by 50 per cent in less than ten years) as wishful thinking. Our laboratories and factories will continue to find ways to produce more and better goods with a lower expenditure of time, effort and cost. But we cannot expect the physical science to carry the whole load.

There has been a growing realization in American industry that great untapped opportunities lie in finding ways to develop more fully our human resources. Technological advances and the increasing complexities of managing under today's and tomorrow's conditions have made manager development a necessity as well as an opportunity. Those who have been closest to this field believe that an opportunity exists in General Electric to increase productivity 50 per cent in the next ten years through better management alone (4, p. 184).

Cordiner is pressing the point that as management matures, it finds more advantageous ways of dealing with people so that group effort will be more effective. He implies that these future improvements will come about as management learns to translate the aspirations of people into motivations for creative purposes.

Role of the Industrial Engineer

The question is, what position will Industrial Engineering assume during this transition? Will it be on management's first team or in some subordinate role?

It is important that we reflect on this. For this is a definite trend away from the primacy of task-centeredness, from emphasis on things, that has been the hard core of Industrial Engineering's stock-in trade. In short, this requires not only a re-examination of the Industrial Engineering basic definition, but also of the role its professionalism should take.

Let us therefore turn to the definition of Industrial Engineering that was developed by the Long Range Planning Committee of AIIE in 1955:

> Industrial Engineering is concerned with the design, improvement, and installation of integrated systems of men, materials, and equipment. It draws upon specialized knowledge and skill in mathematical, physical, and social sciences together with the principles and methods of engineering analysis and design to specify, predict, and evaluate the results to be obtained from such systems (13, p. 98).

The key words here, in the emphasis I am placing, are: *It draws on specialized knowledge and skill in . . . social sciences.* The words *social sciences* deserve considerably more attention than we Industrial Engineers have given them thus far.

So much for definition. Now with regard to professionalism, Donald K. David says this:

> Mere technical competence in the affairs of business and in administration is not enough to qualify a businessman for either success or leadership. No man can be really competent in the operation of a business in doing his part in the production of goods and services without giving thought to the effect upon his own business not only of the rules and regulations imposed by society but also of its current hopes and aspirations (1, p. 130).

On the specific subject of the personal responsibility for professionalism by the individual Industrial Engineer, M. E. Salveson has made this valuable contribution:

> Indeed, the Industrial Engineer now must give his field a "new look", define his objectives in the light of his enlarging job, and prepare to meet the coming challenges. For, surely as a man is measured by the problems with which he is confronted, so also will our profession be measured. Whether that measure be reduced to time study and quality control or expanded truly to Industrial *Engineering* lies collectively in our hands (9, p. 22).

Our hands, he says, not management's, not anybody else's, *our* hands.

The Long Range Planning Committee of AIIE also issued an important pronouncement at the Cornell Symposium concerning the profession of Industrial Engineers from which I quote:

> Motivation is the mainspring of attitude. Seeking to render service as the prime motivation is the overriding objective of any professional endeavor. This need not exclude other motivations, such as economic ones. Yet one of the hallmarks of professional attitude is recognition of the service motive as the supreme target. A profession . . . cannot demand recognition by the public. It must earn this, like respect, by deeds not just by words. Thus action, not merely creeds, is required before democratic society is willing to bestow the distinction of professional character upon any activity. In that endeavor, the progressive philosophy of the Industrial Engineer is the key ingredient for ultimate and lasting success (13, p. 99).

What is our philosophy—or, what is *my* philosophy—is a question over which we well might ponder.

As a sort of footnote to this excellent summarization, the dynamic aspect of professionalism is stressed by James L. Schuler of the Bureau of Ships when he says:

> As professional men we should strive to keep our professions moving. We should neither deride nor fear new names, new languages or new ideas. If we must deride, then deride stagnation (10, p. 36).

So as we move forward, it seems that we must also move upward. It is inescapable that the professional plateau will have to be much higher in the future. To meet successfully the challenge of the years immediately ahead, we must establish better criteria for the profession of Industrial Engineering. This will require concepts that are much broader, much deeper. These are new dimensions fitting into complex social equations of a higher order.

If we should be able to do this, Industrial Engineering will find itself flowering into the full professional maturity that can be its destiny. If, however, Industrial Engineers settle for something less than their best, it is quite conceivable that, as Dr. Salveson has warned, they will find themselves pre-occupied with techniques for productivity improvement within the framework that is commonly referred to as "task management". Task management concerns itself primarily with things; and, although they are important things such as output, cost, schedules, and margins, the danger is that Industrial Engineering, as it seeks to implement industrial management, will likewise give its primary attention to things. Important though they are, these approaches will not lead us away from the distressing climate—nor will they alleviate the causes of the climate—out of which have formed the ominous clouds alluded to by Schweitzer and Trueblood.

What I have been talking about is the need of all of us who presume to guide and direct the actions of others, whether in line or staff, to achieve for ourselves an adequate philosophy for personal living that can give us stability, inner poise, intuitive common sense, empathy, maturity. Also an overall broad view (Weltanschauung) for, as Clarence Randall (former Chairman of the Board of Inland Steel) has said, "This . . . has been the aim of the philosopher through the ages: the opening of men's minds to the relationship of the part to the whole (8)." We industrial Engineers must deal with the whole of this complex reality that is our life's work and not let ourselves get lost in the maze of interacting parts.

Mr. Randall made a further observation that ". . . the art of management, even in an industry that rests for its success on the achievements of the scientist and the engineer, requires a broadly cultivated mind (8)."

Cultivated Mind

What is a cultivated mind? About a hundred years ago, Cardinal Newman spelled this out in the following statement regarding liberal education:

> . . . (It) is the education which gives a man a clear, conscious view of his own opinions and judgments, a truth in developing

them, an eloquence in expressing them, and a force in urging them, it teaches him to see things as they are, to go right to the point, to disentangle a skein of thought, to detect what is sophistical, and to discard what is irrelevant. It prepares him to fill any post with credit, and to master any subject with facility. It shows him how to accomodate himself to others, how to throw himself into their state of mind, how to bring before them his wont, how to influence them, how to bear with them. He is at home in any society, he has common ground with every class; he knows when to speak and when to be silent; he is able to converse, he is able to listen; he can ask a question pertinently, and gain a lesson seasonably, when he has nothing to impart himself; he is ever ready, yet never in the way; he is a pleasant companion and a comrade you can depend upon; he knows when to be serious and when to trifle, and he has a sure tact which enables him to trifle with gracefulness and to be serious with effect. He has the repose of a mind which lives in itself, while it lives in the world, and which has resources for its happiness at home when it cannot go abroad. He has a gift which serves him in public, and supports him in retirement, without which good fortune is but vulgar, and with which failure and disappointment have a charm. The art which tends to make a man all this is the object which it pursues as useful as the art of wealth or the art of health, though it is less susceptible of method, and less tangible, less certain, less complete in its results (5, p. 32).

This is an excellent overall summary that can be a hallmark for personal growth and professional maturity for Industrial Engineers who wish to make a really significant contribution in the years ahead to the future of America.

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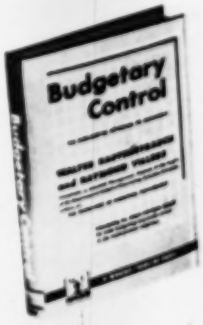

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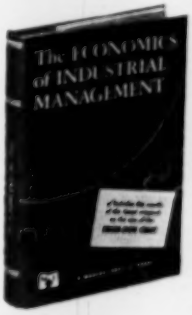

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Methods Engineering and Automation

By Robert S. Rice

Associate Editor, Factory Management and Maintenance

The trend toward greater mechanization of operations in manufacturing industries is accelerating. Capital investment and employee productivity data tend to prove this statement. Also, observation of the industrial scene makes the truth of this conclusion apparent.

What is automation?

This mechanization of operations is loosely characterized as the automation movement. But which applications of machinery and equipment are properly examples of automation, and which are mechanization of a lesser degree? These questions confront us with a need for definitions, a need, however, which is largely academic.

For example, at an International Harvester Company technical conference, Mr. R. C. Archer, Vice President, Manufacturing, said (and I quote):

> In our own manufacturing plants we have found it beneficial to utilize automated equipment for many operations. . . . You will see examples of a number of these applications. . . . I am sure that you will find it difficult to determine whether the processing employed is 'mechanization' or 'automation.' *The differences are of little interest to the Harvester Company. We are interested in both if they provide us with lower costs, higher quality, greater safety, or improved working conditions.*

In *Practical Automation* (McGraw-Hill Book Co., Inc.) the authors handled the problem this way (and I quote):

> This book's viewpoint of automation is broadly inclusive. That is because industry interprets and applies automation this way. In essence, . . . automation is the currently popular brand of technological progress concerned with increasing productivity wherever people work.

The Methods Engineering Problem

For the main purpose of our discussion this broad view of automation will do. The question that faces those concerned with Industrial Engineering policies and practices is not one of defining automation. Their problem is that of planning and administering a methods engineering program with enlightened recognition of the automation (or, mechanization, if you prefer) trend.

Does automation threaten to eliminate the need for traditional methods engineering program? Automated machines and production lines provide tremendous cost and production advantages. Manufacturing cost reductions of 80% have been noted. Automation has multiplied the output of some processes by several times. Certainly these are benefits that are worth pursuing. But first sight of some automated processes is awesome. They are complex structures, often involving unique applications of electrical, electronic, hydraulic, pneumatic, or mechanical technology. Their rough design is beyond the ken of the average methods engineer.

The engineering groups that conceive, design, and install these "monsters" are *not* displacing methods engineering. There are two reasons: one, despite the speeding trend toward automation, there remains, and there will remain in our time a preponderance of "unautomated" operations in need of improvements that methods engineers can generate; and two, there is work for methods engineers that is directly and indirectly related to automation projects.

H. B. Maynard, President of the Methods Engineering Council firm of management consultants, is in a good position to observe the effects of automation on methods engineering. He says:

> It seems to me that, from the beginning, Industrial Engineers have been interested in the mechanization of repetitive processes. They have been able to design the simpler types of gadgets and work assisting devices themselves, and have worked cooperatively with tool designers and machine designers on the mechanical devices that require a specialized skill in design. There will be many (plants) where so called "whole automation" is not practical. Here, it seems to me, the Industrial Engineering function will be performed as it always has been.

Is automation relegating methods engineering to a less important role? No, emphatically not. Actually, the opposite is the case. A large automotive company, for instance, appears to have attached real significance to methods engineering after it had committed itself to automation.

Thomas M. Ware, Administrative Vice President of the International Minerals & Chemical Corporation, thinks that:

> . . . the Industrial Engineer must be much more broadly trained in his ability to perceive problem situations, and to conceive of fresh, tailor made approaches that may be used to solve them, drawing broadly from engineering, economic, and management skills.

However, from the comments of these men, and from the comments of many others, it is clear that methods engineering, as conceived by alert and thoughtful executives, is changing under the influence of automation.

In an article in the November-December 1955 issue of *The Journal of Industrial Engineering* D. G. Malcolm, National President of the AIIE at that time, writes:

> A look at the new Industrial Engineering is certainly an exciting and pertinent subject to explore, for we are in an era when technological change seems to be coming at an ever increasing rate. . . . All of the factors are causing serious shifts in, or additions to, the approach required of the Industrial Engineer. . . . I should like to mention a few factors that are accelerating this gravitation toward the 'new' industrial engineering.

First in the list is automation, under which Mr. Malcolm discusses the relative rise in indirect labor and the need for new techniques for measurement and control.

The changes in methods engineering are evolutionary, not revolutionary, in the same way that automation represents an evolutionary development in technological progress. For convenience these changes are classified as they relate to organization, training, program, and techniques.

Organization

Methods engineering is first affected by changes taking place in the organization of all plant activities. Here are some pertinent comments:

T. J. Schumaier, Manager, Standards Department, Century Electric Company: "As automation affects many departments, it must be approached on a team basis."

Thomas Ware: "I am often reminded that future executives must be spawned who know how to parlay the values of many specialists. . . . Today there is necessarily a high degree of specialization. . . . We need to know how to employ specialists to advantage; in fact, we have no alternative. . . . The Industrial Engineer has his place in this."

The growing need of specialists in engineering and management is observed. At the same time, they express the need for ways and means to coordinate the work of many specialists. Probably this is our most serious plant organization problem today. There are more staff and service departments, more functional groups. Now we are adding operations research, automation, and other functions. We are building more organizational fences. And, as you know from experience, methods engineering must get through, over, or around these fences in the normal course of carrying an improvement project through successive steps from idea to installation. How is industry attempting to solve this problem of efficient communications among its specialist functions?

Note the title of Thomas Ware, previously quoted: "Administrative Vice President." Establishment of his position represents an approach by coordinating staff activities at the highest practical level of management. His job is to get done the projects aimed to serve the line, or production function.

Another large company established a position of director of manufacturing planning, reporting to the manufacturing vice president, that embraces methods engineering as well as tool engineering, plant engineering, quality control, product engineering, and safety. Again, the purpose is to coordinate these specializing functions at a level that should simplify and speed communications and cooperation among them.

Another approach to cutting inter-department communications red tape is that of assigning teams to projects. A team consists of responsible representatives of all departments concerned with the project to be developed by the team. This method works well for large projects, such as the modernization of methods, layout, and facilities for a production department.

Argus Cameras Division of Sylvania Electric Products Corporation used the team idea on modernization of its finishing department. The Argus Chief Industrial Engineer headed the team which included the finishing department foreman, a finishing engineer attached to the laboratory, the manager of production planning and materials, a methods engineer, and the maintenance supervisor. James Thompson, the Chief Industrial Engineer, feels that the team method provided real advantages, such as: optimum improvement goals, shorter development time, smooth installation, complete acceptance, quick attainment of expected performance in the modernized department.

Either of these organization ideas—integration of related staff departments and project teams—can be used in small plants as well as large ones. The variables are only numbers—number of departments and number of people. But however the methods department fits into the plant organization, whatever the scheme of organization, the methods engineer's ability to work effectively with people with diverse points of view is even more important now.

Within the methods department or group, automation raises the question of need for more specialists within methods engineering. Should we add men versed in electrical and electronic controls, for example, and other engineering areas to our methods groups? A few say yes, most say no, others feel it depends on what you have and need from a plant-wide viewpoint.

H. B. Maynard comments:

> The close relationship between Industrial Engineering and tool and machine design has long been recognized. Many companies have these two functions set up under the same administrative head. My thought is that this trend will continue, but I do not see any great changes taking place. If more mechanization becomes feasible, the size of the tool and machine design groups will be expanded. I do not see Industrial Engineers taking over this function themselves as long as there still is the kind of work to do which Industrial Engineers ordinarily handle.

Most agree with this point of view so far as the *work* of methods engineers is concerned. Electrical and other engineering specialities concerned with equipment design are well established outside the area of Industrial Engineering. It does not seem desirable, or even feasible to try to change the traditions that have developed naturally.

However, we have two relatively new specialities which appear to be gravitating toward Industrial Engineering, and specifically, into the methods function: statistical

analysis and data processing. New York University recently revised its Industrial Engineering curriculum to place more emphasis in these areas. D. G. Malcolm, in the article referred to earlier, discusses these activities at length as major additions to the content of Industrial Engineering practice. At this stage of development particularly, these two fields are specialties.

A third possibility for specialization within the methods engineering function is materials handling. Many plants do have specialists in handling methods, largely for two reasons: development of methods and equipment for handling has been moving very fast during the past decade; and two, the opportunities for improvements in material handling practices are numerous and very rewarding.

The automation movement is expanding the practice of assigning engineers to specialized work. In discussing the relationship of automation with methods engineering we logically cannot avoid the question of specialization within the methods unit.

In practice, methods specialties include: manual work analysis, or motion study; tool and fixture design; plant layout; material handling; data processing; statistical analysis; and so on. Also, you can have process specialists, such as machine shop analysts and others.

If the size of your program and organization will permit any specialization among your methods engineers, the advantages outweigh the disadvantages. You stand to gain additional operational savings by concentration of knowledge and effort, refinement of analysis and development techniques applicable to the specialty, and possibly better engineering performance on individual projects. The major disadvantages, of course, are: the omission of broad training and experience desirable for promotion of engineers; and, the establishment of additional communication and coordination problems.

Training

Automation adds considerable emphasis for the need to maintain a continuing program of training for methods engineers. Many years ago we used to think of training only in relation to the initial work period—variously from the first day to the first month or two—of a newly employed engineer. Today we recognize more generally that training is a continuing process throughout the period of employment.

The automation movement, too, points up the need to train methods engineers along two separate but parallel paths. We must provide our engineers with the opportunity to learn the new techniques that are useful in methods work, such as linear programming, predetermined time standards, and so on. At the same time we should provide the opportunity for our methods engineers to keep abreast of technological developments related to the business or industry in which they are employed.

A methods engineer should be familiar in a general way with the newest processing equipment and methods in his industry. There have been many cases of the waste of the time of a methods engineer attempting to get a 10% saving out of an operation by improving manual motions when he could have suggested purchase of a newly marketed machine that would effect a 50% net saving—if he had known about the machine. And he did not need to understand fully the design of the machine.

Professor James Apple states:

> The methods engineer must be more of an engineer and less of a technician. This may require that those persons now performing methods engineering functions take additional training in engineering, and it certainly will require that future methods engineers be well grounded in engineering fundamentals, especially as they are related to equipment design, integration, and layout.

And Thomas Ware visualizes the need for broad training when he says:

> The Industrial Engineer must be much more broadly trained in his ability to perceive problem situations, and to conceive of fresh, tailormade approaches that may be used to solve them, drawing broadly from engineering skills, economic skills and management skills.

Program

Traditionally, we have set up methods improvement programs by listing departments, products, or functions (inspection, for example) that appeared to need attention, and add specific projects on which we intended to work. But the aim in general has been to find individual operations—small pieces of the total production process—to improve, and then to develop improvements.

The automation movement is effecting some change in this concept of program. There is today a growing trend to broaden each project in the program. The program starts in the same manner with a list of departments, products, and functions that need attention. But the aim is a large-scale modernization of the entity. In other words, the tendency is to make a big project of each item in the program. Automation of the process is considered. Some degree of enlargement of mechanization generally is inherent in the final plan.

There are two basic causes behind this broader approach: the high rate of technological development; and the necessity for aggressive battle with rising costs to remain competitive.

This broad approach to problem solving has to be initiated somewhere. The alternative: A methods engineering group can wait for someone else to suggest a broad project, and wait for assignment of work to bits and pieces of it. Visualizing and defining a broad project and getting approval to explore it require big thinking, the capacity to shoulder major responsibilities, and leadership. It is challenging. But the rewards are commensurate. Many Industrial Engineering departments are accepting the challenge.

No good methods program, however, can be limited to projects of broad scope. Many of the most troublesome plant problems that need the attention of methods engineering are those of a very limited nature—one operation

that slows a production line, one point of inventory build-up, a single paperwork process, and so on. They must be included in any plant's program. Minor improvements solve problems that are extremely important to individual supervisors, and the aggregate net savings can be significant if not impressive. A really important aspect of programming small projects is to get results—get them done quickly, efficiently, and satisfactorily.

As in the case of the big projects, the opportunity to automate or mechanize exists in small projects. The addition to a machine of automatic feeding and ejection of materials, or application of program control to automate a machine are commonplace methods improvements today. Good methods engineers must be aware of the technology and alert to the potentials of application—even though incapable of designing the application.

Automation is effecting changes in labor mix which should be considered when you are projecting a methods improvement program. The proportion of indirect and maintenance workers, compared with direct labor is, increasing. There will be a correspondingly growing need for methods engineering work in these areas.

Another opportunity for methods engineering that is becoming more significant is the determination of type and location of machine and equipment controls. The problem is similar, in some respects, to the familiar one of workplace arrangement, and the same principles apply. In addition, there is a new area of exploration in relation to the type and location of instruments and signals to facilitate viewing and reaction on the part of operators.

There are many other types of projects to be considered for a methods engineering study. They are not new ideas, but changing conditions in industry and new techniques can affect their relative importance for any one plant. There are make-or-buy studies, storage methods, packaging methods, and application of new materials, just to name a few. You might argue that material specifications are the responsibility of product design. But please consider two pertinent facts: first, product materials affect the cost of making the product; and the second, integrated engineering not only permits, but requires exchanges of suggestions among the various engineering and staff functions.

Techniques

The methods engineering activity in a plant that is following the trend toward greater mechanization uses all the techniques that are traditional. But a few newer tools warrant special consideration in relation to automation. The three discussed here provide examples, rather than an exclusive list, of the need of methods engineers for a variety of tools and techniques to work successfully in an automation climate.

Work Sampling

Work sampling has been explained so thoroughly in other articles, and in books, that there is no need here for definitive discussion.

Obviously, an Industrial Engineer can use work sampling for many purposes, related to all his functional activities. Considering methods engineering only, we find an increasing use of the technique for two purposes: to spot the needs and opportunities to improve methods; and, to obtain information needed to aid the solution of a methods problem and to justify a change proposal.

For instance, you can use work sampling to learn the utilization of equipment and indirect labor time, the cost of materials handling, the effectiveness of maintenance labor, and others already familiar to you.

An automobile manufacturer used work sampling in a deliberate attempt to improve the effectiveness, by improving methods, of a 75-station trim assembly line. It took four engineers only four days to make more than 30,000 observations—enough to get a reasonably accurate picture of what was going on at every station on the line. Methods engineers then went to work more intelligently, beginning with operations that needed improvement most, and using the work sampling information to guide balancing of the line as well. The advantage in using work sampling was the saving of time in determining where to concentrate methods improvement effort, and in obtaining factual data needed to analyze present methods and to justify changes.

Another company used work sampling to find out where it could best improve materials handling practices. Its plant is a fabricating shop, building a variety of heavy equipment. There is a high volume of diverse material movement.

Observers made sampling records over a long period of time—two or three months—to sample a variety of work and shop conditions. They observed the activity of materials handling equipment – predominantly industrial trucks and overhead traveling cranes, in this instance—and operation delays along with their causes. In analysis, the methods engineers concerned themselves largely with the delays related to the handling and movement of materials.

Guided by a large amount of information, the engineers were able to recommend changes in equipment assignment within a short time after the observation period had ended. The recommendations were practical, they were based on facts. The resultant changes effected a reduction in job cycle time—speeded the flow of materials and work through the shop.

Methods Improvement Training

More and more companies are increasing the number of employees contributing to methods improvement by training people outside the Industrial Engineering or methods department in methods improvement techniques. Perhaps you're thinking that this is not a methods engineering technique. You're right if you are going to restrict your view of the Industrial Engineer's job to the performance of his personal work in the field of methods. But if you'll accept a broader view of his job—to develop and maintain a program of continuing improvements in meth-

ods then probably you will agree that the Industrial Engineer should consider utilizing this means of enlisting others in the effort to obtain methods improvement objectives.

The primary objective is to stimulate the volume of methods improvements, with a corresponding increase in the magnitude of cost reduction. There is also a by-product benefit to methods engineering. It can be freed of small improvement projects to the extent that permits the methods engineers to emphasize large-scale, broad improvement projects. This is the type of project, discussed earlier in this article, that is more and more associated with the automation trend.

For example, the Mueller Brass Company has a work simplification activity *and* a distinctly separate methods engineering group.

It trains line supervisors and key staff people in work simplification techniques, having started several years ago with Allan Mogensen training. (By the way, the experience of this company has been that eighty per cent of practical and significant improvement ideas come from supervisors, engineers, and key staff employees, so it concentrates its work simplification program with them.) These people then become completely responsible for development of an idea right on through installation. Each does himself whatever is required — contacts to get advice, data, and approvals (if required); selling the idea; and direction of installation. Of course, he gets help from staff departments, but it's technical help, not menial services. This company requires each person trained to install one improvement project per month. The penalty for omission is loss of a portion of his bonus for that month. The accounting department provides follow-up audits for management control of the program.

In addition, the company has a methods engineering group that obtains improvements by deliberate search and persistent analysis. It takes the areas where there are cost problems, surveys them thoroughly, and develops recommendations for improvements of methods.

Methods Analysis Guides

The common approach to deliberate improvement in process methods is to question everything about the process, and let the answers guide improvement. All of you are familiar with this technique. The keys to effectiveness of this system are: to ask the right questions; and to get adequate answers to the questions.

Toward this end many general check lists of questions have been developed, and many have been published. Probably many of you have your own check lists. Many companies are using such aids.

One company has gone further in the direction of developing check lists and analysis forms than most. Its methods engineers are using many different forms, one for each of several categories of operations. But there are cases in which an engineer will use two or three of the forms for one operation — if their application will help.

Some of the forms are familiar tools for methods analysis. They include: process, or flow chart; act analysis (right- and left-hand) chart; a movement, or operation analysis form; and a cost comparison (present vs. proposed) form.

In addition, they have some check lists and forms especially designed for their processes. These include: assembly; material handling; fabricating; and others.

This is a significant idea, one that is especially useful in the case of highly mechanized processes. And it can be expanded to provide a set of guides or as many classifications of processes as a company might require. Also, these check lists might be maintained currently to include specific equipment and method application ideas. Such a system could provide in writing a means of making "cross-fertilization" of ideas more effective.

Predetermined Time Standards Systems

Some time ago *Factory Management and Maintenance* made a survey of the experiences of companies using a predetermined time standards system such as MTM, Work Factors, BMT, ETS, and MTA.

Seventy-eight per cent of the respondents said they utilized their systems for methods improvement. Sixty-six per cent said they used their systems to select methods prior to production.

As a matter of fact, the systems appear to be more widely used for methods engineering than they are for standards development. Sixty-six per cent said they used PTS for incentive standards, and thirty-five per cent for daywork standards. (There is some overlap in these percentages because some companies indicated usage for both purposes.)

How do they use PTS for methods engineering? A case in point is that of the Birtman Electric Company, Rock Island, Illinois.

This company, a manufacturer of electric irons, vacuum cleaners, jacks, and vises, won a contract for an electrical firing mechanism for a missile — and a set of "how-to-make problems." It consisted of 70 parts, some quite small, and required close tolerances. In short, Birtman personnel were unfamiliar with some of the assembly requirements.

The company had to meet a full assembly schedule in a short time. Before the deadline it had to: 1. design and build the fixtures that would be needed; 2. figure out how many fixtures, tools, and operators would be necessary; 3. iron out the inevitable bugs in the new assembly process; 4. plan the layout of work stations according to motion economy principles, and make the installations; and 5. train the operators.

Birtman's methods engineers planned the assembly operations in their laboratory. Sub-assemblies were divided among several two-man teams. Along with each idea for performing an operation each team analyzed motions required and calculated time required for the operation from their tables of motion time values.

By this means the engineers were able to select practical

and economical methods, and plan the balancing of operations before any equipment was set up in the shop. The solutions of all the problems mentioned earlier were facilitated by having reliable time data during the planning stage.

A mechanized process is more costly to design and install than one that is predominantly manual. The greater investment in a mechanized process makes down time more costly. Therefore, it is more important to plan carefully and accurately the methods of operating the process. PTS is a useful technique for preproduction development of the operating methods.

Summary

When automation begins to spread within a plant it creates new demands upon operating functions and controls. Methods engineering, too, is affected. It becomes even more indispensable because methods design is required to guarantee optimum results. But the methods engineering problems and projects are broader and deeper. They require change and adjustment to meet the challenge of automation to methods engineering. It was the purpose of this article to examine and discuss these changes.

Button, Button, Who's Got the Button*

By Edwards R. Fish, Jr.

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How many times have we as IEs been asked to explain our profession to a layman in answer to the question "just what is it you do"? Not an easy question to answer clearly, and the trouble is compounded by the fact that there are so many of us now that the profession as a whole has found it necessary to seek an answer which is brief, concise, simple and directional. Is there an answer yet? Is the profession cohesive enough to permit a single statement of its purpose and methods? Or will we have to play "button, button" for a while yet, reaching into many pairs of outstretched hands to find the answer by elimination? Certainly the Long Range Planning Committee's statement of the Industrial Engineering field has shortened the process, but a great deal remains to be thought, written and spoken before a full understanding of our professional purpose will be possible.

Functions of the Industrial Engineer

I would like to suggest that much progress can be made toward such an understanding if members of the profession will individually challenge their own jobs to see just what they are trying to do. Bert H. Norem, writing in the September-October issue of the *Journal of Industrial Engineering*, makes the point that the engineer should aim for excellence in the particular work he is doing, not try to claim competence in all and sundry phases of the field. The engineer shall be known by his actual accomplishments, not by what the profession's definition says he should be able to do, according to Mr. Norem.

This is a very sound point of view, which can be carried even further. For instance, we should explore this thought in more detail as it relates to the condition of IE accomplishment in the small business firm. Perhaps by so doing we can learn more about how to carry out our professional purpose in a particular field. Now, the typical small business employs fifty to two hundred fifty employees, and is run by five or six key executives, who are headed actively by a president. It operates under a rather loose organizational plan and has a rate of growth which will not soon change these conditions. This is the kind of business which usually employs one or less IEs, and represents a fine potential for the right kind of professional assistance.

It may be well to define the nature of this assistance. What kind of results are we after, and what accomplishments will warrant recognition as a true professional assistant and provide a service to the employer which is not otherwise obtainable? This is the true test of a professional's worth - to render a service which increases the effectiveness of his employer and which cannot be obtained in equal quality from any other source. For instance, the controller provides a specialized knowledge of financial

* An entry in the First Annual Professional Paper Contest sponsored by Seattle Chapter, American Institute of Industrial Engineers.

management and budget formulation to control use of the company's funds. The sales manager offers a particular combination of leadership and market sense, which is necessary to the life of the business; and the personnel manager performs a truly specialized job in assuring a stable, competent work force.

The Industrial Engineer's service must be as distinctive and indispensable as each of these if he is to be recognized as a true professional aide to his company. He must be able to bring about smoother operation of all these other functions over the long pull, provide a continually more accurate sense of direction to the whole concern, and lead everyone in the group in effecting sound economies. Knowledge of the usual tools of the trade—statistics, time and motion study, incentives, flow charts, etc.—is essential of course, but concentration on these techniques is often incidental and certainly should not be the IE's principal function *in the small concern*. His work needs to be more like a piece of "enabling legislation" which opens the way by showing methods which the local departmental governments can use to run their affairs more effectively.

For example, a paper processing plant's IE, when asked to evaluate the work of the plate-making shop, discovered a familiar situation. A series of technical changes over the years had gradually eliminated much of the work formerly done, but the crew had not been reduced in proportion. A simple chart illustrating the situation enabled the superintendent to size up the correction required and make the necessary changes effectively. In another case the same engineer worked with the production scheduler to help him gather and present information to the general manager, which led to an immediate program of press capacity addition. A simple machine load analysis method, which the scheduler controls, was developed at the same time to show the direction of future equipment purchases.

To determine how the IE can be sure of rendering his particular service effectively in the small company requires a further study of some of the special conditions found in this kind of organization.

Decision Making

The first of these conditions, under which the engineer must learn to work effectively, is that decision-making authority is usually held very closely at the top level. Nearly every small business is heavily influenced by one man because it is "his business" and he makes the guiding decisions. After all, wouldn't your own business be the same way? The "boss" has his own formula for success, usually based on past results, which has worked for him and which he is not likely to change quickly. Anyone wishing to affect the direction of the business or its policies must understand this formula. To be effective the IE must constantly consider and appreciate its importance, for much of his work is concerned with adapting it to new thoughts and conditions. Many otherwise capable engineers are thwarted because they fail to realize the importance of this pattern to the chief executive's conduct of the business.

For instance, a young engineer working for a medium-sized household furnishings plant, owned by a veteran merchandiser, attempted to carry out a series of time studies in the plant without a full understanding of the owner's purpose. He failed miserably, not because the time studies were bad, but because the owner had built a successful business on a flexible sales and style policy, and instinctively resisted a premature attempt to standardize his operations which were contrary to his success formula.

Economic and Mental Barriers

Another feature of the smaller-sized firm, which the IE must consider in his work, is the existence of economic and mental barriers to many of the Industrial Engineering tools, both old and new. Money is a problem in varying degree to any size concern, but in the smaller businesses the allocation of working capital is of prime importance. To select two simple examples: a delay or wrong move in providing plant facilities can lose enough sales volume to make the difference between profit and loss; or inability to finance inventory at the proper time can cause either costly shutdowns or loss of business. Because of these limitations, working capital is in constant demand for the necessities, which to most small company managements are the "sure things" with a predictable payoff period—plant, equipment and inventories. It is thus easy to see why these managements have a sizeable mental barrier to spending anything for the advanced management techniques of the IE. Even though most capable executives agree that logical engineering analysis and detailed operation study can minimize business risk and improve application of working capital, they may still be reluctant to take funds away from daily operation of the business in order to pay for them. In other words, "seat of the pants" management methods are often dictated by financial considerations, and can be changed only as rapidly as more modern management methods prove their ability to earn more money than they cost.

The Flexible Organization

A third important consideration in relating IE to the small business unit is the lack of clear definitions for functions or departments within the organization. Duties often overlap, department heads usually work closely together on a personal basis, and systems are adjusted informally to suit needs as they arise. Sales problems are promptly converted to factory action; and financial crises reflect immediately in purchasing policy because of this adaptability. Fast footwork is the small firm's only real weapon against the crushing weight of large competitors. The small organization survives and grows because it is a single flexible unit with the ability to direct all its talents quickly in any direction. If a product needs to be rede-

signed, the four or six key people can usually work it out on the spot, or if a sudden large order develops, a few minutes' get-together works out the production schedule changes required. Because everyone is thus "in harness" and directly involved in the daily responsibility of keeping the business going, there is very apt to be spoken or implied criticism of the presence of staff personnel. IE under these conditions becomes a process of educating and influencing an organization on the run, *without retarding its rate of motion* or *restricting its freedom of action*.

Conclusion

There are three primary distinguishing features of the small business organization—the boss's success formula; the financial and mental barriers to introduction of advanced IE techniques; and the amorphous, flexible organization. These now form a background for some conclusions about the place of the IE. Realizing these conditions, what can the Industrial Engineer do to increase managerial effectiveness and provide a more sure sense of direction for the enterprise? There is certainly one thing he should not do. He should not become a "methods man" or "cost reduction engineer", jumping from pillar to post on call from foreman or superintendents. In the first place, such spot assignments have a baffling way of shifting location rapidly; and in the second place they are usually only a surface indication of deeper and more important defects. Here is an actual example from a recent experience: in a glassware plant, valuable warehouse capacity was being wasted by inaccurate placement of palletized loads of finished product. When a correction was attempted, lift truck drivers immediately pointed out that their trucks were in very poor condition and could not efficiently work in such close conditions—an assertion which was amply justified by the facts. Therefore, the maintenance department was instructed to overhaul the equipment. However, it soon developed that such a project would require months to complete because the repair crew had been reduced some time earlier to save cost during one of the recurring periods of low sales volume. The plant engineer was reluctant to hire more mechanics, only to lay them off again under pressure of the next economy drive. A study of this situation finally revealed this company's major weak spot. Production volume could not be stabilized because there were no intelligent sales forecasts, nor could there be a reasonable labor cost budget to guide department heads, such as the plant engineer, in maintaining an efficient crew. So finally the important problem was found—a problem which had not had the objective attention of management because its importance to the operation was not realized. The real trouble was one of focusing management attention, not of methods or operation improvement in the shop. As such, it had to be handled at the management level by a gradual increase in understanding of the true difficulty and a shift of policy to meet it. This was eventually accomplished by the IE, over a period of about a year and a half, and the company is now well on its way to accurate production forecasting and realistic manufacturing cost budgets.

In this story is the clue to the IE's importance in the small business world. Owners and managers of these businesses need, and usually very much want, someone in the organization with ability and training to direct their objective attention to unrealized weaknesses, but such help must be a part of the management itself. In no other way can it work with the special success formula, or with the flexible, shifting organization pattern so often found in this kind of business. Take another look at the official IE definition. It speaks of "*integrated systems* of men, materials and equipment" and how to "design, specify, predict and evaluate the results to be obtained from such systems." As Mr. Norem states, "this is a very broad statement of the work of the IE." It is also a good statement of what management of a small enterprise must do regularly. Evaluation, design and installation of changes is the essence of management in the small, mobile organization, but it is traditionally accomplished by a small group from "close in" with little or no help from outsiders.

Engineer in Management

What is needed in these firms is an engineer in management to take the lead in more logical analysis of the basic problems which hamper daily operation, by directing, or coaching, or pointing, the efforts of the other organization members to solve them. To do this he must often take over line administrative duties in order to get close to the operation, and to demonstrate the soundness of his methods. This *engineer for management* moulds himself into company plans and policies in such a way that steady progress is made without disturbance while he shows others in management how to apply new methods to solve their problems. He becomes a part of the company in order to practise his profession effectively. In the small company the professional IE must learn to apply his science in day-to-day terms from within. His service is no less important than that supplied by the practitioners of the many new and advanced analytical techniques for large applications, for he must not only understand his tools but be able to make them work single-handed. This requires good judgment and willingness to assume full responsibility for results.

Application of the IE definition to actual practice in the world of small business certainly does not change the definition in any significant way. It has not been the purpose of this discussion to change the definition. Rather, I have tried to describe a particular field of application in the hope of improving general understanding of the IE's professional purpose. If others will do likewise, we will soon have a body of thought sufficient to clear up the confusion with which we are now beset.

Report to the Eighth AIIE National Conference on the System Simulation Symposium

By Warren E. Alberts

Director of Industrial Engineering, United Air Lines, Chicago

The purpose of the Symposium was to bring together men from all over the country who were working in the general field of simulation as applied to business and military systems. The growing interest and experience in the use of simulation techniques had suggested that a meeting of practitioners, wherein problems, experiences and results might be discussed then summarized and published, would be of real value to the practitioners and a service to management, the management sciences and engineering. My task is to pass on to you some of the highlights of the meeting which occupied the time of some 20-men for a day and a half.

In a very real sense, the Symposium represented a pioneering effort in bringing together people from many fields, societies and organizations to discuss their work in this relatively new area. It also represents the first time that a meeting of this type has been jointly sponsored by the American Institute of Industrial Engineers, the Operations Research Society of America, and The Institute of Management Sciences. The actual Symposium was under the direction of a Steering Committee, with Dr. Tom Caywood representing ORSA, Dr. D. B. Hertz representing TIMS, Don Malcolm representing AIIE, John Arwood acting as the Host for the AIIE Chapter, and your speaker as Chairman.

The Symposium was limited to 20 and was by invitation only. Invitations were issued on the basis of the individual's work in the field, and his ability to contribute to the Symposium. Due to the extreme newness and potential of this field, the Committee is sure that many individuals who could have made significant contributions were not included. However, there was no way to determine in advance the extent of their work, and we had set a limit of 20 to facilitate discussion. As it was, we were extremely pressed for time.

Following are the participants who, in addition to the Steering Committee, took part in the Symposium:

Mr. R. G. Brown, Arthur D. Little	A General Purpose Inventory Control Simulation
Dr. R. L. Chapman, Rand Corp.	Simulation for the Training of Air Force Personnel
Mr. Richard W. Conway, Cornell Univ.	Evaluation of Alternatives on Profits
Mr. W. C. Dalleck, United Air Lines	Operational Model of a Waiting Line Problem
Mr. G. J. Fenney, Stanford Research Institute	Selection Among Alternative Models
Dr. H. B. Galliher, Massachusetts Institute of Technology	Monte Carlo Methods
Dr. W. W. Haythorn, Rand Corp.	Simulation of the Air Force Logistics System
Mr. Edward L. Howard, California Texas Oil Company	Model of the Entire Enterprise
Mr. N. H. Jennings, Port of New York Authority	Computer Simulation of a Bus Terminal Operation
Dr. Jack Moshman, Council for Economic & Industry Research, Inc.	Establishing Deviation Limits for a Complex System
Dr. I. Reszucka, IBM Corporation	Simulating the Shop Scheduling Process
Mr. Franc Ricciardi, American Management Association	Top Management Decision Game
Mr. Patrick J. Robinson, Imperial Oil Company, Ltd.	A Distribution Network.
Dr. T. C. Rowen, Rand Corp.	Simulation of the Air Defense System
Mr. A. J. Rowe, General Electric Co.	Machine Shop Scheduling Problem, in conjunction with Dr. Resuki
Mr. Harry Rubin, Air Materiel Command	USAF Aircraft Engine Management Model
Mr. Emil Schell, Remington Rand Corp.	A Review of Early Simulation Efforts
Dr. Frederick P. Thompson, General Electric Company	Simulation of the Strategic Air War
Mr. Strother H. Walker, Johns Hopkins University	Simulation of the Quartermaster Supply Problem
Mr. Jack Weinstock, Ramo Wooldridge Corporation	Inventory Control Solution by Simulation

Since time began, man has made models, facsimiles or representations of reality, the purpose being to learn from them, test ideas, and predict what the effect might be if he acts in a certain way; in other words, man's efforts to comprehend his environment. Webster says that simulation is to attain the essence of (not necessarily the appearance of) without the reality. When we talk about system simulation, we are talking about duplicating the essence of either a business, military or other type system in a way that we can work with it. It may help to briefly cite some of the practical examples and applications on which the participants of the Symposium reported. Remember, these are highlights.

In the military area, we heard a report on the simulation of the entire air defense system. Basically used for training, this simulator, employing over 200 people, is being used for over 2,000,000 training hours annually. The criteria has not been realism in the simulation, but to try and elicit the same response as the real situation. In this way

it can be determined what men learn, why they learned it, and what their expected performance will be in actual operation of the system. The report on the simulation of the Air Force Logistics System, a model which will deal with over 1,000,000 items and controlled on an exception basis, is in an advanced stage of development. Here the model is being set up to compress real time and deal with complex logistic problems spanning years in a matter of days. Another report was on the simulation of the entire Strategic Air War where 4,000 aircraft are operated in real situations on either side and 72 hours of warfare can be compressed into 8 hours of computer time.

In the queueing, or waiting line, problem area a very interesting report was made on the study of a bus terminal operation during a peak hour. Imagine the problem of fitting 17,000 people into 320 busses in one hour. In this case the model is being used to balance the service aspects with economics in order to give the best possible service to the traveling public.

Another paper was on a simulation of the different types of customer services rendered at a busy airline ticket counter. Discussed were the costing of the different levels of service and comparisons of universal versus specialized counter types. Almost every industry has this type of waiting line problem where there is no real solution but the objective is to find a balance between the length of wait and the costs involved.

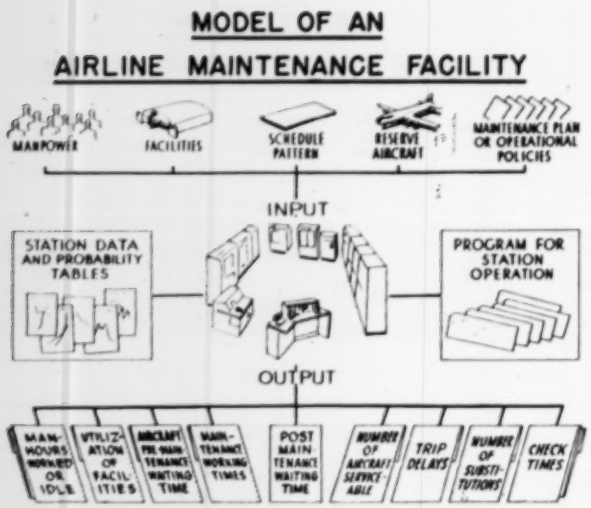
There were quite a few reports made on problems in the inventory area. In one case, a firm is devising a general program to handle a certain class of inventory problems for all types of industry. Another report was on work going ahead for the Army Ordnance System where the problem is one of handling and controlling 400,000 items in 7 supply depots. The distribution problem of a manufacturing company handling some 10,000 items was discussed, along with the distribution of an oil company whose network covered some 1800 field plants. The model developed for the Quartermaster Corps, which can simulate 100 calendar quarters in 30 seconds for different categories of goods, was discussed. In the aircraft engine management field a model is being developed to include all the variables in the distribution, maintenance and supply of military aircraft engines in the continental United States.

Now, jumping to an entirely different type of model, a presentation was made of a top management game which simulates for top executives the decisions involved in competing with other firms on a game basis. This has been reported in several magazines and the newspapers recently. The value is not so much in training executives to make decisions as it is to broaden their viewpoints and make them aware of the inter-relationship of the information that they deal with and the need for better information on which to base their decisions and planning.

One of the ideas being explored is the development of a model which will simulate the entire workings of a corporate enterprise including developmental, production, distribution and sales networks all over the world. The plan would be to work towards the integration of a company's data processing and communication system with a model which can be used not only to record what's going on and the trends involved, but also at any given time represent the essence of how the organization actually works, which means it can be used to forecast and test ideas for the future. In this way management has, for the first time, a *corporate laboratory* where at any one time they can be fairly sure that they have a model of the enterprise which is being continually refined not only by the instructions that they pass out, but also the results as they are fed back in. This will not be an easy task and will take many years to achieve; in fact, it will have to be done on a building block process. However, it is important to recognize the importance of this type of objective in the future design of over-all management systems.

One of the toughest problems in the management field is that of production scheduling, and there have been many attempts to apply techniques which will improve performance in this area. One of the models reported dealt with the scheduling of a machine shop. The objective is to minifnize the problems of lateness, inventory costs, and idle time. The model deals with some 63 groups of machines and labor pools with various skills. It truly simulates the operational essence of a machine shop. However, it does not give magic answers, only the results assuming different work, inputs and changes in the basic parameters.

Now, to take this system simulation and model business out of the mysterious realm in which you may be viewing it, I would like to show you a symbolic picture of a model which we started working on in 1954. It, in no way, is representative of all types of models and it does not give one right answer. Its job, in this case, is to simulate the actual operation of the entire maintenance situation at one of United Air Lines' major stations. In the case of this particular model, we tried to simulate the operation in an analytical or mathematical fashion. However, we found that we could not do it at the present state of the art so we elected to use a computer and introduce the variables from real life by what is known as the Monte Carlo method. All of the important variables were measured including their probability of occurrence. As you can see, we use a large computer to do the actual simulation, and on one hand we have introduced the data which we have collected over a 4 months' period from the field, and then on the other side we give the machine a logical set of instructions which enables it to reproduce the essence of life and call upon the data as it is needed. Then as input into the model, we can see that we can introduce or change the number of men on each shift, the facilities required, the schedule pattern, and our maintenance philosophy. As output, we get reports such as one would actually get in actual operation. However, in some cases, we get information we couldn't actually obtain such as the number



of men idle by 15 minute periods. In this model we are simulating 100 days of operation in a little less than 12 minutes. It is important to remember that these models make no decisions; they are only a tool for management but their potential is dramatically apparent.

This is a brief review of the highlights of the Symposium as far as the reports went and an example of one of the models about which we talked. To cover the discussion period we will pursue basic questions; the type that you or I would ask if we were completely unfamiliar with the subject.

First of all, let's ask the question, since we're talking about system simulation, "*What is a system?*". This is a definition we decided not to spend too much time on. As you can probably guess, a system is anything you want it to be. It is identified by the boundaries you or your associates draw. An Industrial Engineer or business man may think of a system as the use of men, machines and materials to achieve a given objective. The objective in some cases is to produce or distribute goods and the system can encompass the whole company or any part of the process. True systems are not restricted by organization charts or departmental lines.

Now, we've talked about models; "*What is a system model?*" Well, here again, it is not so important to describe the model itself as to define what it is. There was general concurrence in the definition that a system model is a symbolic representation of a system which has, for a given purpose, the desired characteristics of reality. With this in mind we can now proceed to a definition of system simulation, which is simply the use of a system model to reproduce the essence of actual system operations.

Our next question might well be, "*What kinds of models are there?*" Without drawing too fine a line or getting in too deep, it looks like there are three. First, the physical or visual model which looks like what it represents and is exemplified by a map, a proto-type of a new aircraft, or the layout of your new plant. The second type of model can be called an operational or analog description of the operation. Here may be used a straight-forward, logical step-by-step sequencing of operations as they exist in real life. An example of this type of model is the waiting line model or the aircraft station model which we just covered. The third type of model is called an analytical model, and its interactions can be stated in mathematical form. Actually, all workers in the model field seek to express a system in an analytical form. However, in real life there are often so many variables and probabilities to be handled that the means to handle this in an analytical form, plus having it understood by the people who are going to have to work with it, has not been developed.

It is important to remember that as in real life the physical and operational models do not produce any one right answer, but either give you as output operational data or the means to make comparisons between alternatives. The analytical model, on the other hand, if applicable can be used to arrive at an optimum answer for certain conditions. We have talked about the Monte Carlo method; maybe we ought to offer a definition. It is a computational method or technique of introducing data of a random or probabilistic nature into a model. Its purpose is to reproduce data in the same manner as would occur in a real life situation.

Now, we may well ask the crucial question. "Why should business men, management scientists, or anyone as far as that is concerned, be interested in simulating a system?" Well, there are some pretty important reasons, and they are as follows:

1. *For purpose of experimentation or evaluation;* in other words, to try and predict the consequences of changes in policy, conditions, methods, etc., without having to spend the money or taking the risk to actually make the change in real life.
2. *To learn more about the system* in order to redesign or refine it. The very complexity of most of our business and industrial systems makes necessary a means to provide understanding of both the system as a whole and of its parts.
3. *To familiarize personnel* with a system or a situation, which may not exist as yet in real life.
4. *To verify or demonstrate* a new idea, a new system or approach; in other words, quantify the risks and benefits, and demonstrate the chances of success.

Now, let's take a look a little deeper behind this question, "*Why simulate?*". What are some of the specific advantages which are not so apparent when one tries to generalize. Well, first of all, simulating a system enables one to compress or expand real time. In other words, a business man can simulate a year of his operation in a matter of minutes or he can slow down the process so that he can, like a slow motion film, analyze just what is going on in his problem areas. We are trying to alert the manager to the fact that here, for the first time, he is going to have a laboratory which enables him to analyze his business and look at it either in slow motion

or in high speed. The second advantage is a tremendous one, because it's at the heart of the business man's need to plan and forecast. He can, with system simulation, look before he leaps and test his ideas and changes in advance. The results of a year's operation under different assumptions can be his in a matter of hours. Tied in with this is the fact that in many cases it is impossible, impractical or uneconomical to try many management ideas today because of the disruption or cost involved in changing a going operation.

Now, speaking to the Industrial Engineers, you gentlemen have set forth your goal of becoming the system designers of the future. If so, you must help devise methods of testing those designs someplace else than on the production floor. The trial and error method of testing system changes, in most cases, is too costly or impractical. The complexity of the scheduling process alone in most industries today demands the development of a means to simulate the over-all operation. So to you this field of system simulation may well represent your laboratory for developing and testing management and industrial systems.

We who have participated in this Symposium have shared some real experiences, and we are enthusiastic about the future of this field. However, no one is more aware than we are of the many problems that lie ahead. System simulation is no cure all, neither does it give any magic answers; it is a tool, a management tool, and like all tools, what it produces depends on the user. Also, let me assure those who may feel the water is too deep that the concept is far more important than any of the techniques involved. The field requires imagination and a down-to-earth grasp of how business and systems operate as a whole.

It is the consensus of the participants that we should follow this Symposium with others dealing with certain major projects in the field and talking more about the methodology and the principles which can then be passed on to other people entering it. There are many areas requiring research and several efforts which require support and recognition. This we will try to do. Also, we feel there is a need for the practitioners in this field to communicate more in management's language. After all, they're the customer.

I would like to express our appreciation, and those of the Symposium participants, to the Eighth Annual Conference of the AIIE for so graciously hosting this Symposium and especially to John Arwood for his skillful handling of all the arrangements. Thanks, too, from the Steering Committee, to each of the participants who so freely gave of their time and knowledge.

This ends my brief report to you. A research report on the Symposium will be available at the end of the year. Copies may be obtained at $1.75 each, from AIIE Headquarters, 145 N. High St., Columbus, Ohio, or from the other sponsoring organizations.

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The Role of the Industrial Engineer in Systems Design and Improvement

By Arthur D. Even

Pilot Project Officer and Ordnance Consultant, Integrated Engineering Data Processing System, Ordnance Tank—Automotive Command, U. S. Army

In adopting the current definition of Industrial Engineering, this Society has officially recognized the important role of the Industrial Engineer in the field of systems design and improvement. This discussion is concerned with that portion of systems technology covering engineering records and data processing. Fortunately for the Industrial Engineer, this field is almost untouched. Most engineering operations no matter how large are still using the engineering drawings and records familiar to our forefathers. However, today there are a few teams in Industry and Government who are developing the necessary technology for the improved data processing systems of tomorrow.

War and waste have long been associated with each other, and it is true that the engineering operations of the Military Establishment are exposed to more drastic changes in volume than are most commercial organizations. In the case of manual systems, these variations in volume are expensive and somewhat wasteful. Battling backlogs of work with large numbers of inexperienced personnel and long hours of overtime are inevitably followed by losses of highly experienced and valuable personnel during the staff reductions of peacetime. And during "cold war" periods, people can be either overworked or underworked as programs change. To remedy this condition, the top management of Tank-Automotive Ordnance initiated, in 1954, a long range modernization program with a view toward building a system sufficiently flexible to cope with extreme variations in volume while operating at all times with a small, efficient staff—a real Industrial Engineering challenge. The first year and a half were spent in a thorough analysis of the manual system, a review of the work that others had done, a detailed study of the actual needs of various organizational elements and the manner in which these requirements could be best satisfied, the documentation in book form of the analyses and studies, discussion with various equipment suppliers, and finally the preparation and submittal of the necessary justification for a new system to higher authority. This proposed system was approved and established as an Ordnance Corps Pilot Project in order to concentrate the effort in developing and testing a system which could be used by the entire Corps. This has become a four phase program, as indicated in Figure 1, involving hundreds of engineering personnel, working with millions of records and decentralized around the globe.

Phase I

Phase I primarily consists of the use of punched cards, punched paper tape, and microfilm in such a manner as to eliminate the manual processing and handling of certain records and documents, and to provide for the more economical printing, storage, and transmission of copies of drawings and supporting documentation. An important element is the Drawing Record Card, shown in Figure 2, which replaces three documents of the old system—an antiquated type of book record, a full size print of the drawing and a microfilm having four times the area of the new. In addition, the film in this card can be enlarged using high speed processes, or used to make film copies at rates upward of 1500 per hour. The punched card feature allows for the mechanical searching and filing of the card to satisfy demands for prints and for replacing out-of-date revisions. Possible savings, in terms of reduced materials handling costs and transportation, are also enormous. Indicative of the Industrial Engineering nature of the systems design, is the division of the active Drawing Record Card file into two sequences—high usage for mechanical handling and normal usage for manual handling. In this manner the amount of equipment and the overall processing times are reduced to a practical minimum. Also, a two-deck operation permits batch type processing in the one deck and random access in the other, thus reducing the unit cost of the longer lead time items while still giving

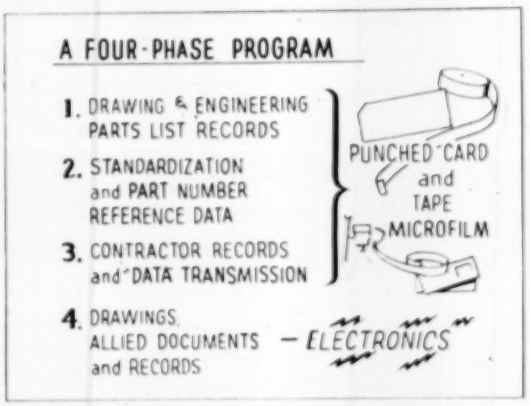
A FOUR-PHASE PROGRAM
1. DRAWING & ENGINEERING PARTS LIST RECORDS
2. STANDARDIZATION and PART NUMBER REFERENCE DATA
3. CONTRACTOR RECORDS and DATA TRANSMISSION
PUNCHED CARD and TAPE
MICROFILM
4. DRAWINGS, ALLIED DOCUMENTS and RECORDS
— ELECTRONICS

Fig. 1

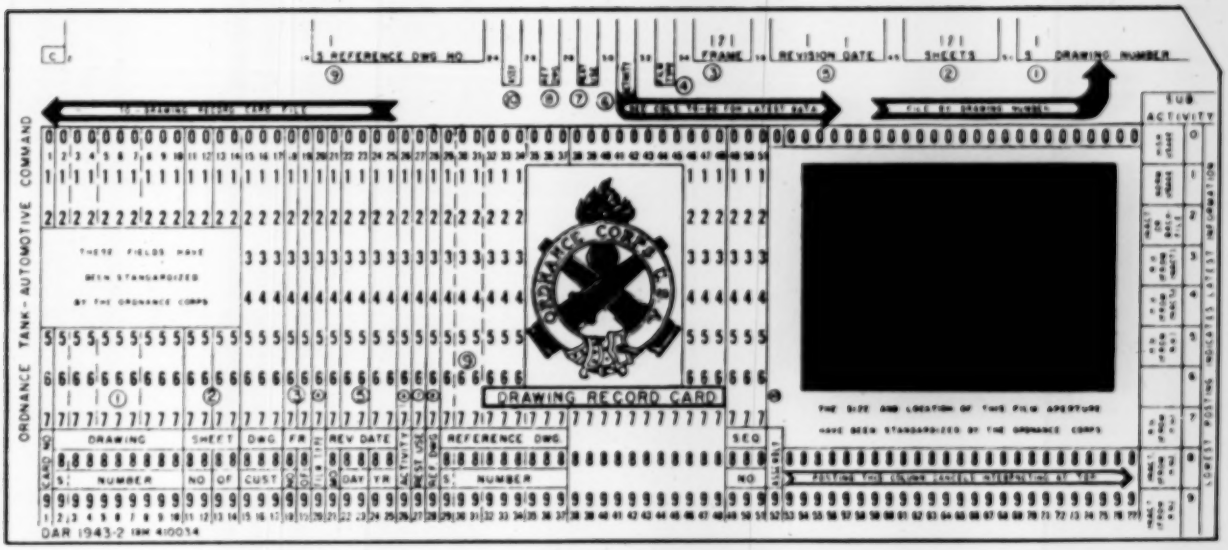

Fig. 2

rapid service to those who must have drawing data on short notice.

Phase I also includes the typing of the engineering parts list on an electric typewriter which is capable of simultaneously typing, reading punched paper program tape, and generating this type of tape. The unchanged portion of the list can be retyped from the program tape automatically at 110 words per minute. The typed lists are filmed and placed in cards, as are the drawings. The punched paper tape, received as a by-product of the typing, is used for two other purposes. First, it is exploded in a tape-to-card punch to get the Usage Location Index, a basic engineering record which indicates in which assemblies the various parts are used. And second, this card is then reproduced into the Exploded Deck Follower Card (same data but a different format) as a tool for determining assembly component drawing requirements and for producing cards for system output.

Phase II

Phase II joins two major efforts. The first consists of providing the standardization engineers with microfilm copies of drawings mounted in punched cards and properly coded to aid in reducing drawing search time. The second contemplates an improvement in the present manually-posted part number interchangeability file. Here again, it is described to reduce search time and also to speed printing out of data.

Phase III

This phase is a little more difficult to explain as it will involve a more comprehensive mechanized liaison between the central engineering data repository and the various contractor engineering facilities. It is intended, during this phase, to continue efforts to standardize record-keeping and data processing documents and to improve data transmission generally. This will undoubtedly include closed-circuit television, high-speed printing equipment, transceivers, and any other such equipment which can be economically used to improve service within the engineering orbit.

Phase IV

This portion of the program is concerned primarily with the rapid handling of those engineering records containing multiple variables. In this category are the part, model, drawing, and engineering order number relationships which are so important for engineering control and for contractual purposes. Because of the nature and volume of the data, a straight punched card system has been determined to be impractical. At the present time, it appears that random access, electronic equipment will eventually be adopted in this area. Another possible improvement being observed with a great deal of interest involves that extremely interesting combination on a single film of the image and a means of electronic sorting of films at extremely high speeds.

Present Phase

Now that the entire scope of the program has been mentioned, it might be well to take a closer look at the present portion of the program—Phase I. In order to quickly achieve the anticipated drastic reductions in processing time, personnel, operational costs, and space at the central repository and to improve the drawing quality, records, and general data transmission, it is necessary that existing manual records be converted as rapidly as possible. And, it is recognized that only through filming the original drawing—in lieu of copies—can the best film be secured, existing drawing quality measured, and action

taken to provide the necessary drawing rehabilitation. In order to film the maximum number of original drawings, microfilming is being decentralized to twelve stations, each of these capable of filming at least one thousand drawings per day. All exposed film is forwarded daily to a single processing station and returned immediately to the central repository for preparation of the aperture cards and for mounting of the film therein.

Programming Input

Here, as in other manufacturing operations, the manner and order in which work is to be done is of interest to the Industrial Engineer, because the mechanical-electronic system requires that much care be devoted to establishing work flow on a formal, documented routine basis to assure the maximum utilization of equipment and the higher priced personnel. In this system, there are two kinds of input—engineering parts lists and drawings. Figure 3 illustrates the engineering parts list input processing flow, beginning with the actual typing of the list and ending with the filing and distribution of the finished cards. Drawing data input is almost identical to the routine covered by the lower portion of this chart beginning with the filming of the hard copy of the engineering parts list.

Programming Output

Although this project is still basically in the input stage of Phase I, the routines for output have been worked out. This has been necessary in order to assure that the required input information is placed in the system in a form usable for output. Figure 4 illustrates the flow of the drawing output routine. Again this is even more interesting to the Industrial Engineer, because at this point the comparison between manufacturing in the factory and production in the office becomes more noticeable. Output is much more complicated than input, because a whole complex of variables is encountered. For example, if a customer requisitions a drawing by part number, this number must be converted to a number which is meaningful to the system—the drawing number—as quickly as possible. If the demand requires component or reference prints, in addition to the print of the item itself, means must be available for rapidly determining which of these additional prints of drawings must be supplied. In other words, the assembly must be exploded into components just as is required for the physical manufacture of the assembly.

Film legibility will often determine the method of handling the demand. In some instances the drawing will be on record but will not have an adequate microfilm, or the drawing may not be available in any form. In these cases, it is necessary to route the demand through the exception process (old manual system) in order to secure the drawing and to provide the best print possible. Then also, the customer's choice of reproduction type must be considered. In some cases the requisitioning activity will be geared to the handling of film and will prefer this medium. In other cases, enlargements will be desired. Each type of reproduction takes a different series of processes. In addition, the former requires the preparation of a punched card prior to reproduction. In each case the actual master film card will be used to service the demand.

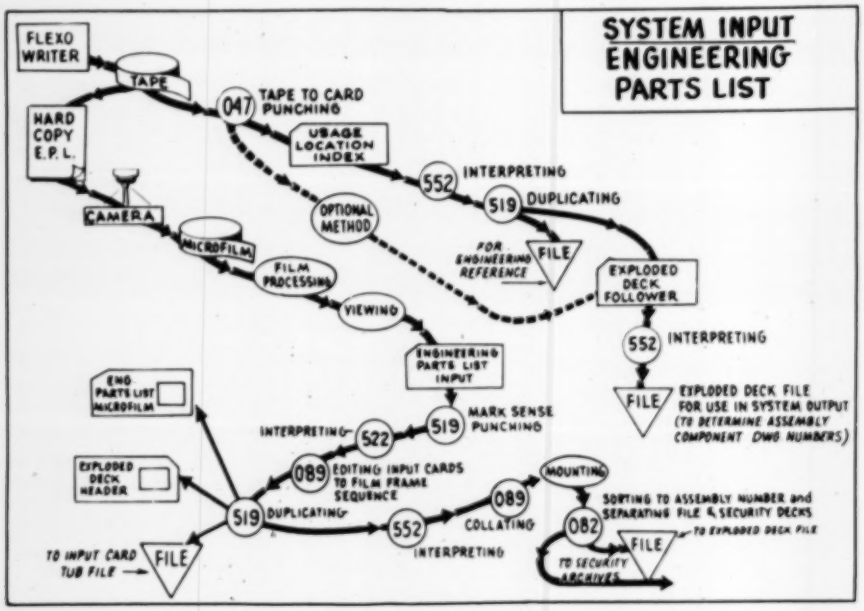

Fig. 3

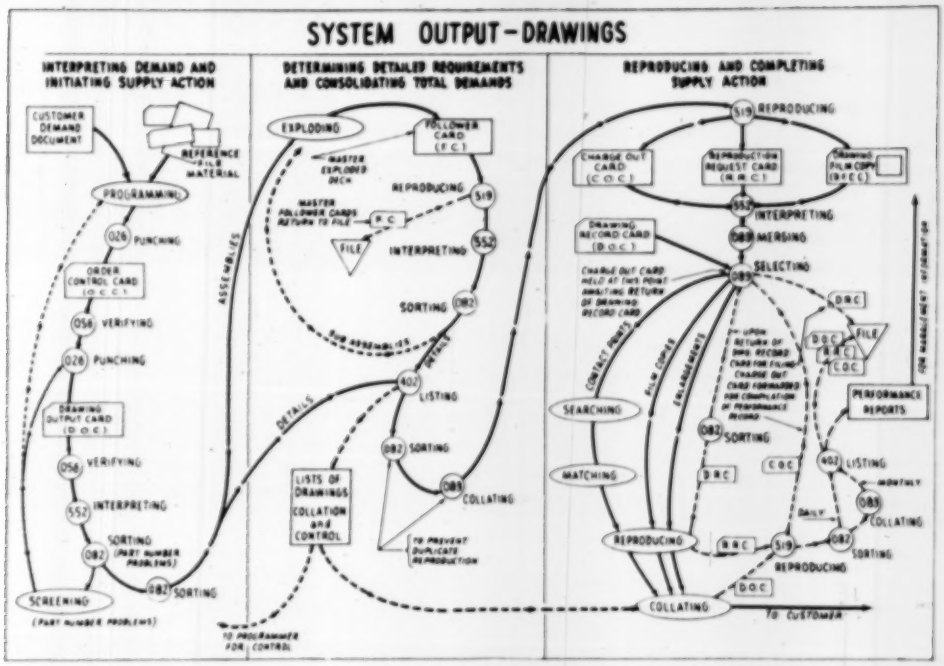

FIG. 4

Getting back to the exception process, this system will operate only upon transfer of the demand from the standard system. Action will be initiated by the receipt of a demand card plus certain other documents. Additionally, the exception process will also have access to the exploded decks and other processes of the standard system. On this basis, it can readily be seen that the output of the organization will be controlled in such a manner as to supply the best product, in the most economical manner, and in the shortest time.

Additional Process Information

In addition to the general flow charts previously discussed, the complete Industrial Engineering procedural package for each job or task will include detailed flow charts, as shown in Figure 5, and the same information regarding raw material, the finished product, and set up and operational instructions for each machine-clerical operation as are required for other manufacturing operations. Also, each job will be formally scheduled and machine loads tabulated. As the nature of the system requires that the data in the system be current, it is intended that there be no backlog in the system. This requires accurate production data requirements so that additional machine time can be borrowed from other organizations, a second shift activated, or necessary overtime scheduled. For the people responsible, bringing production techniques to the office is a welcome relief from the semi-controlled conditions prevalent in the large manual systems.

Reference Data Required

From the previous discussion and illustrations, it can be readily seen that the new system will operate at maximum effectiveness only when the major portion of the work can be programmed, scheduled, and processed through the complete production routine. As soon as a job, or any portion of it, is moved into the exception process (old system) it is susceptible to the same delays and reduced productivity of a manual system. A possible exception will be improved processing, based on utilization of certain tools of the new system, such as punched card charge outs, reproduction requests and listings as previously mentioned. About the best way to maximize use of the high speed system, and minimize routing into the exception, is to have all necessary data available and be able to use it. This means that, in addition to the necessary machine time and personnel, it is essential that provisions be made for interpreting all demands into language which is meaningful to the system. For example, demands from overseas stations for prints of drawings usually are identified by the service activity's stock number. Engineering, on the other hand, has not recognized the stock number but has spoken only in terms of drawing and part numbers. To bridge this gap in system language, it has been conventional in the past for engineering to request of the service activity of the headquarters, all of the known part numbers carried as references against the stock number. This usually involves the manual writing of from one to fifty numbers and/or symbols to identify the organizations concerned. Engineering then checks the part number and

Procedure No. G1
5 April 1957
Chart G1-A1
Sheet 1

CONSOLIDATED FLOW-OPERATIONAL CHART

CARD PUNCH OPERATOR

1 Removes first segment of source document file.

2 Reviews first card.

3 Prepares program card in duplicate, per Process Sheet G1-B1.

4 Places one program card on Drum.

5 Holds second card for future transmittal to Verifier Operator.

6 Punches one card for each source document, completing one segment of cards at a time, per Process Sheet G1-B2.

7 Assembles source documents, cross reference cards, and verifier program card.

8 Sends to Verifier Operator (Program card forwarded with first batch).

VERIFIER OPERATOR

9 Places program card, received from Card Punch Operator, on Verifier program drum.

10 Verifies cross reference cards versus source documents per Process Sheet G1-B3.

11 Reassembles source documents in file and returns.

12 Forwards cross reference cards to Processing System Equipment Operator.

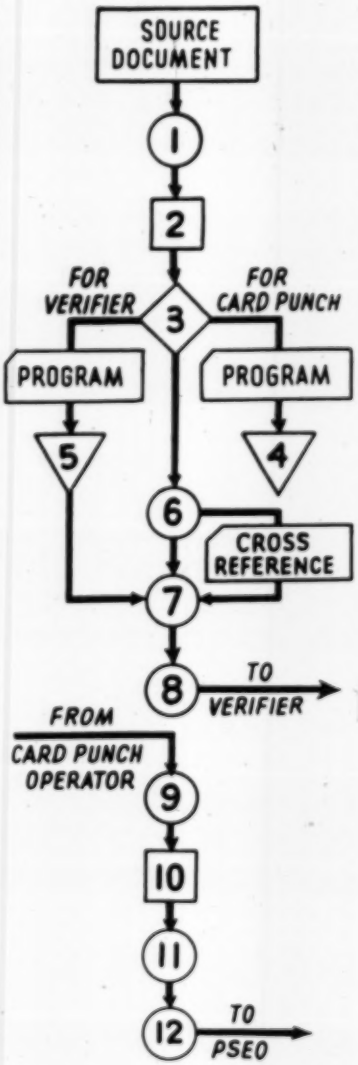

FIG. 5

drawing number files, both agency and commercial, in an attempt to locate a drawing. Obviously, if the new system is allowed to operate on this basis, a high percentage of demands would circulate through this involved process. Therefore, it was decided to build a stock number to drawing number file, in order to identify the necessary drawings from the stock number. This is just one example of a tool recognized by the Industrial Engineer as necessary for uninterrupted flow of work through the system

Usage Sequences

In addition to observing the need for two separate decks of identical drawing record cards to permit economical batch processing from one while at the same time servicing short lead-time demands on a random access basis from the other, Industrial Engineering has recognized that equipment-time limitations will make it necessary to restrict the mechanical removing and refiling of cards to those having high usage. Therefore, the current drawing record cards are to be carried in two sequences—the 50,000 most active in the high usage sequence and the balance in the normal usage sequence. Accumulated demands can be mechanically matched against the high usage drawing record cards and mechanically collated. Those not so handled can be handpicked from the normal usage file or the backfile. This entire area of file control, with emphasis on mechanical card handling, provides an interesting challenge to the Industrial Engineer.

Reproduction

The element which makes this system different from most other punched card systems is that of reproduction—an area which, until recently, has been pretty well geared to the speed of the past. Today the engineering drawing, which used to be considered acceptable if faintly discernible engineering data could be captured on a blueprint, must be capable of taking its place in high-speed data processing cycles consisting of a whole combination of processes. For example, although the new system's first generation copy of the drawing is a film negative, the second generation can be any number of types of reproduction—dry or wet process film copies or enlargements. These second generation copies in turn can be processed into further combinations, including paper contact prints. Determination of the best process-quality-cost combination to meet specific conditions is the kind of work which the Industrial Engineer does every day. This reproduction field offers special opportunities for improvement because of the many combinations of processes and the rapidly advancing technology.

Approaching Systems Design

The system designer, in addition to developing new methods, must be prepared to do something about a new organizational structure and possible plans for replacement of all or part of the old organization. It is not possible in the space allotted to give a completely detailed, step by step account of the actions to be taken. However, it can be assumed that all or most of the following basic actions will be required:

1. Selection of one or more people to make the study. (The effort can often be speeded if consulting services are employed.)
2. Advice to the operating organization of the purpose of the study and introducing of the survey team to the supervisory personnel of the operating organization.
3. Review of the old operation, including the gathering of a complete supply of the old forms used, case studies (e.g. filled orders of varying degrees of complexity), organization charts, operation manuals, work logs, performance figures, personnel strengths, and any other information necessary to indicate the nature and volume of the work performed, the kind and size staff employed, the type and size of operating area, the type and adequacy of the equipment, and any other facts relevant to the study.
4. Organization of data into a book or manual describing the nature of the basic work, the order of flow, the organization elements concerned, the basic forms used (e.g. what engineering does regarding drawing numbers, the preparation of the engineering release, the recording of drawings and all essential reference files used in the process).
5. Study of other more advanced systems having similar or related elements of similar scope and magnitude.
6. Development of a basic plan, testing it against the demands of the old system, and discussing it with key supervisory personnel and modifying it if required.
7. Discussion of plans with equipment manufacturers.
8. Selection of the final plan and preparation of a justification for submittal to higher authority. This justification should describe what is to be done, its impact on present operation, its advantages in terms of improvements and cost reductions, the cost of operation and equipment, personnel and space needs.
9. Detailed system design (after authorization) including the design of necessary cards and forms, the ordering of equipment and material, the securing of necessary space allocations.
10. Development of the necessary organizational structure for the new system, including a complete functional statement, necessary job descriptions and recommendations in terms of personnel pay and ratings.
11. Establishment of a program for securing necessary personnel both in terms of locating and training existing personnel and people new to the organization.
12. Implementation of the necessary training beginning with formal schooling and carrying into on the job training.
13. Preparation of the required procedures for the flow of the work through the system, including necessary charts and machine programming and operating instructions.
14. Progressive set up of the work area upon receipt of necessary equipment, according to a predetermined plant layout.
15. Set up of necessary reference material and conversion of required old system data (e.g. old book or card type drawing records) to input data for the new system.
16. Beginning pilot runs of data into the new system.
17. Modification of system elements as required during the earliest practicable phase of the pilot operation.
18. Provisions for assuring that additions and revisions of data are properly synchronized between the old and new systems.
19. Gradual phasing out of the old operation in favor of the new (e.g., discontinuing of posting of new and revised drawing data into the old books and cards and mark sense programming into the new system).
20. Disposal of equipment, record material, space, and personnel no longer required.
21. Completion of necessary procedural documentation, official

orders and instructions, clearly explaining the new organization and its relationship with the old (if necessary).

Organization

As previously mentioned, a major element in this system design has concerned organization. After necessary study, it was decided that the new system could not be built on the old concept of the functional machine room where all electric accounting machine work would be done in a regular tabulating room, and all drawing-engineering parts list reproduction in the conventional reproduction room. Instead, the new system recognized the need for an integrated effort in the handling of incoming and outgoing work. It was decided to place all incoming work in an input section and all outgoing in an output section. This organizational concept was adopted to minimize the transfer of work between supervisory areas, and through the elimination of these barriers, to perform more useful work with less personnel.

Once that the basic organizational idea was adopted, a complete mission statement was developed, and a proposed manning table, including quantity of personnel for each job established. This personnel allocation between the Data Input, Data Storage, and Data Output Sections reflected the personnel requirements submitted to top management in the project justification. Another interesting feature of the organization plan was the inclusion of two technical staff assistants—one for systems technology and the other for graphic reproduction technology—reporting directly to the Chief of the Integrated Engineering Data Processing Branch. This line and staff concept was believed necessary if the new operation was to continue to develop and to adopt the latest of systems and reproduction methods and equipment. In addition, the positions of Junior and Senior Programmer were established in order to have available personnel who were capable of planning and following work in and out of the system. Another interesting element involved the establishment of the position of general purpose machine operator. Here it was believed that the general flexibility objectives of the program could be better met if electric accounting machine skills were added to those of the present reproduction operators. This made it possible to retrain the maximum number of the existing staff and reduce the number of replaced personnel to a minimum. All of these points mentioned involved heavy reliance on Industrial Engineering to assure that the new activity was organized for optimal performance.

Personnel and Training

After the personnel needs were officially recognized by the approval of the manning table, it was necessary to take an inventory of the staff to determine which people had the background, experience, and capability necessary to operate the new system and to assimilate the required training. Although much of this review involved formal testing, a great deal of this information was acquired in discussions with personnel in conference sessions scheduled for enlisting the support of the people and allaying their fears as to the possible impact of changes on their jobs and work lives. During these discussions, the scope of the program, effect on the old system, type of work, method of aptitude testing, method of selection for training, possibilities for advancement, manner and magnitude of staff reductions, sacrifices in terms of schooling, additional supervisory loads, and the like, were explained. Fortunately, because the operating personnel were convinced that the implementation of the new system and the phasing out of portions of the old were to be done according to a fair plan which recognized that employees were human beings who not only had personal feelings but also skill, knowledge, and training which the employer was reluctant to lose, the people gave tremendous support to the program. After a long series of tests, people were nominated for schooling based on a plan of qualification.

At this point it might be well to mention that because the system change was to be evolutionary rather than revolutionary, and as the new system did not contemplate 100% replacement of the old one, such factors as age of personnel, general adaptability to new conditions, personal preference for type of work, the rigors of learning new things, the needs of the old system for effective operation, and the intense competition for certain jobs in the new operation were considered. The training plan also had to recognize the availability of training facilities and the need for a schedule which would bring people into the new system at the proper time. During this period, an experienced tabulating machine room supervisor was acquired and indoctrinated in the new system. He then began to oversee the training and to assist in developing the necessary electric accounting machine operating procedures.

Virtually all of this initial training was done without benefit of equipment on the premises, because of long equipment delivery lead times and reluctance to pay monthly rental for idle machines. Once the machines were received, on-the-job training began. After a sufficient length of time, performance was measured against established standards and necessary steps were taken to meet or exceed these standards. It is not intended to claim or to infer that the job of rebuilding an activity is easy. On the other hand, the job is not so difficult that the Industrial Engineer should not take the time and effort to meet his moral responsibility to people currently on the job as suggested by that outstanding Industrial Engineer, Dr. Lillian Gilbreth, in her visit to Detroit some months ago.

Work Simplification

During a long-range program such as this, the Industrial Engineer must chart a course which will satisfy the main objective of the program—a new system plan within a reasonable length of time. However, during the course of this work it appears inevitable that the need for certain changes in the old system will be required. In this case, it is necessary to decide if a diversion to improve the old

system is warranted. In some cases an immediate benefit can be realized and the improvement carried into the new system. For example, in one instance a bottle neck was broken, unit labor expenditure was reduced by 75% in one area, and some manual counterparts of mechanical tools of the new system were introduced simultaneously. This expenditure of time and the slight delay in forming up the new system plan were considered justified in this instance. In addition, the changes have aided in training personnel in the new method.

Selling the System

The old remark concerning the worth of a good idea which can't be sold also applies to systems engineering. In this case, a basic plan was developed which was believed to be feasible and which could be justified on the basis of improved service and reduced cost. It was necessary to present these facts in such a manner that they would stand scrutiny of higher level authorizing and controlling activities. Therefore, a little extra effort was put into the written documentation than is normally developed for an engineering presentation. Fortunately, this justification was favorably received, and later received wide distribution beyond the initiating organization. It is believed that effectiveness of the presentation had some bearing on the fact that the program was designated a Pilot Installation. At various times in the life of a large project, it is necessary that appropriate graphic materials, in the form of charts, slides, and handouts, be available for briefing, indoctrination, and training. The figures previously shown in this article have been taken from the presentation material developed for this program.

Conclusion

It is believed that the renovation of this engineering records-data processing system, and other similar pioneering efforts in this field, are just the beginning of a trend toward the modernization of the large engineering operations of Industry and Government. The Industrial Engineer because of his professional training and background is ideally equipped to recognize the need for improvement and to develop the required system. As a participating member of the improvement team, he will find almost unlimited opportunity for expanding his knowledge and the scope of his operation. In so doing he will expose himself to those job opportunities and satisfactions available to those who contribute to progress.

The Industrial Engineer in Government

By Frank T. Geyer

Chairman, Committee on Government Operations (Pro Tem.)

This is the final report of the Committee for Government Operations appointed by the President, American Institute of Industrial Engineers during the Board of Trustees' Meeting of October 13, 1956.

Basis for Appointment

The President received inquiries from the membership and Engineers outside the organization expressing a desire to know more about how the Federal Government was using the services of the professional Industrial Engineer. The investigations of the various task groups under the Hoover Commission had uncovered many areas in Federal Government that were inherently receptive to the application of the principles of Industrial Engineering. The Engineers were curious about the real and definitive implementation resulting from the recommendations of the fact finding committees. To the Industrial Engineer the objective application of the principles of Industrial Engineering to the Government operations could be measured by the extent of active affiliation of professional Industrial Engineers with the different Federal agencies. This report was written with the objective of answering the related questions not from a critical viewpoint but as an informative report to the membership.

Background for Federal Service[1]

The signing of the Civil Service Act by President Chester A. Arthur on January 16, 1883, established the principle that persons appointed to Government career positions should be selected on the basis of merit. At that time the number of Federal employees was 13,800. Compare this total with the 2,000,000 persons presently employed in Government work all over the world. The Federal Government is the largest single employer. The accelerating demands of ever increasing population and growing complexity of the economy has resulted in unparalleled demand for public service and higher employment in Federal Government. The fluctuation of Federal employment during National crises is immense. Before 1939 the highest employment was 997,000. A peak of 9,786,000

[1] Extracts from press release by Civil Service Commission commemorating 74th Anniversary of the signing of the Civil Service Act of January 16, 1883.

was reached in World War II. Employment dropped to 2,000,000 before the Korean action and rose again to over 2,666,000 during the Korean emergency.

There are more than 70 departments and agencies of which the Commission of Fine Arts is the smallest with three employees and the Department of Defense is the largest with a 1,000,000 civilian staff stationed in all parts of the United States and possessions as well as in most foreign countries. One fourth of the total Government employees are responsible for postal service. Veterans Administration has eight percent. Twenty-one percent serve a multitude of agencies that also help to maintain the American way of life. The work of the Federal employee affects every phase of the American scene from income taxes to narcotic drug control, atomic energy research to forest conservation. These are but a few of the diversifications of Federal activity.

Federal employment is open to United States citizens under the Civil Service Act. Competitive examinations establish lists of successful applicants by job designation. Positions are filled by selecting among those graded highest in the examinations. Only 10% of Federal jobs were covered by the Act in 1883. Today approximately 85% are included for all positions, with ninety-one percent being included for those located in the continental United States. In 1956 the competitive Civil Service became world wide by the inclusion of 20,000 jobs held by American citizens in foreign countries and possessions. Alaskan jobs numbering 10,000 were also included in 1955.

Some of the Federal positions are under a separate merit system. The Foreign Service of the Department of State has 15,000 employees in this category. The Department of Medicine and Surgery of the Veterans Administration has 20,000 and the Federal Bureau of Investigation has 14,400 employees in the same class. The Tennessee Valley Authority employees have a separate merit system also. There are 14,800 persons included.

The Civil Service Commission excepts three classes of Federal jobs from the merit system. These jobs are known as Schedules A, B, and C. Those in Schedule A are positions for which it is impractical to hold any examination. These include foreign posts, chaplains, professional and technical experts to be used for temporary consulting purposes. Jobs in this class number about 237,000. Schedule B is for positions for which competitive examinations are impractical but for which non-competitive examinations are given. There are 4,800 of these positions. Schedule C lists those positions in policy making levels for politically appointed heads of agencies operating in more or less confidential capacity. These may be expected to change with each change in administration and examinations are not given. There are 1200 of these positions in Schedule C.

The merit system as established by the Civil Service Act guarantees the aspirant or career Civil Service worker protection against discrimination as to race, religion, national origin, political spoils system, or rendering political service or tribute in order to retain his job. It further guarantees to the citizen who is not a Federal employee that his Government is administered with the best qualified available people of high standards of personal and moral conduct and competence. The assassination of President Garfield in 1881 brought home the evils of the spoils system and directly focused the public attention to the need of legislative purification of Federal Civil Service controls. The fall elections of 1882 were fought out on the issues of the Civil Service Act. When the Congress met, the first business was the passage of the Act. Several years later the Internal Revenue Service came under the Act with renewed public confidence resulting therefrom. Since its founding the Civil Service system has been markedly free from criticism and has acted in the best interest of the people. President Roosevelt made the observation in 1906 that observance of the spirit and letter of Civil Service law is one of the first indices of a clean, decent, efficient government. President Eisenhower also reaffirmed this principle in 1956 when he said, "Nowhere in the world have I met more efficiency, more dedication, more readiness to serve and to put in hours on end without counting them on the clock, than I have among the Civil Service."

Government and the Industrial Engineer[2]

The Industrial Engineer, as does every man in every walk of life, has the problem of starting his productive life in the right position, to make the correct choice of employer so as to obtain what he alone expects out of the job he chooses, in terms of ambition and qualification. As an engineer the desire to create a useful and beneficial way of life is close to the top of his desires as a professional man. In choosing between Federal and private employment the young Industrial Engineer is faced with the problem of disparity in the starting salary. The Federal Government is nevertheless the largest single employer of engineers and scientists. The 1954 figures show 43,000 professional engineers in Federal service covering 40 recognized professional engineering specialties. The leading divisions were electrical, civil, mechanical, general, construction, hydraulics, ordnance, naval, and chemical. Also listed were design, structural, aeronautical, industrial, agricultural, materials, marine, highway, and safety engineering. The most heavily populated was electrical and electronic with 5320 engineers. The least was lighthouse engineering with three professional engineers. The Government employs ten percent of the engineers and scientists of the nation. Four departments employ ninety percent of all Government engineering personnel. Department of Defense, Department of Commerce, Department of the Interior, and Department of Agriculture. The Department of Defense accounts for sixty-seven and one half percent of the total employed.

[2] News Release USCSC 16 Jan. 57. Address by Philip Young, Ch. USCSC, "The Engineer in Federal Service".

The continuing expansion of the Government scientific and technical programs has created an ever increasing demand for engineers and scientists. The White House Committee on Engineers and Scientists is studying the utilization of the technical manpower in Government programs. Members of this committee are drawn from the top business, scientific, and Government figures. The function of the committee is to advise the President of the United States of the most economical ways in which to use or to apportion the scientific and technical manpower of the Nation. Action groups composed of competent technicians carry on intensive work in fields of recruitment, pay, use, employee attitudes, fringe benefits, turnover, numbers, kinds and levels of engineers in Government. Each finding is compared with experience in private employment practices. The results attained by the groups are consolidated and reported to the Steering Committee. In turn the recommendations of the Steering Committee are given the President for administrative and legislative action on the basis of a coordinated executive branch approach to the problem.

The Salary Question

The starting salaries offered by the Government to the young engineer for certain positions can be less than offered by private employers. This is caused somewhat by legislative lag and inflationary tendencies outside the Government.

The need for periodic wage and salary review for technical positions is recognized by the Government. Revised pay schedules developed by fact finding teams are studied and evaluated. When adjusted to the budget factor a confirmatory review is made of wage practices in private industry and a classification-grade pay scale is set. It is debated through both Houses of Congress and upon passage is referred to the President for signing into law. Upon ratification the Civil Service Commission issues the necessary administrative instructions for effecting the new scale. In the interim the economic aspect of the Nation may have changed from that on which the original revision was based.

The Civil Service wage and salary structure has been criticized as being too rigid with the pay ceiling too firmly fixed and top grades too limited. Action has been taken by the Civil Service Commission to liberalize the authority to pay above minimum salaries in critical occupations as well as to obtain substantial increases in the number of super-grade scientific positions. Currently, the problem of holding technical personnel in Government against more attractive offers by private industry has been aired before Congress in subcommittee hearings. Where Government cost reimbursement contracts are involved, legislators have proposed limitations in contract clauses for salaries to be paid engineers and scientists employed on Federal research and development contracts. In certain instances private interests, having Government contracts and hiring Government Engineers, advertise the availability of positions at the expense of Government.

The following list contains recent legislative actions and proposals introduced in recent sessions of Congress:

HR 9405 84th Congress 2nd Session 20 Feb 56, Mr. Murray, Tenn., Increases number of key positions in NACA to attract top technical talent.

HR 9350 84th Congress 2nd Session 16 Feb. 56, Mr. Murray, Tenn., Increases salary of 275 positions in DOD and 35 in National Security Agency, to be set by Secretary of Defense.

Hearings before the Committee on Post Office and Civil Service HR—A compilation of the testimony submitted in conjunction with the above bills.

HR 2804 85th Cong., 1st Session 14 Jan 57, Mr. Moss—Increases in pay for certain scientific and professional Civil Service employees.

HR 2803 85th Cong., 1st Session 14 Jan 57, Mr. Gubser—Increases in pay for scientific and professional employees in Civil Service.

PL 429 81st Cong., 1st Session—Determines grade in general by describing duties commensurate with grades in Civil Service.

PL 580 81st Cong., 2nd Session—Postpones Classification Act of 1949 for certain employees of Selective Service System.

PL 873 81st Cong., 2nd Session—Administration of performance rating plans for certain employees of the Federal Government.

PL 763 83rd Cong., 2nd Session—Provides certain employee benefits for Civil Service personnel.

PL 94 84th Cong., 1st Session—Adjust rate of basic pay for employees of Federal Government.

HR 1857 and 2161 84th Cong., 2nd Session Mr. Murray, Tenn., Report on additional scientific and professional positions under DOD, NSA, and NACA.

PL 854, 84th Cong., Ch 804, 2nd Session, HR 769—Increases pay for heads of executive department in Federal Government.

Fringe Benefits

While pay is one of the most pressing problems—difference between Government and private industry—the area of fringe benefits in Government compares well with private practice. Vacation periods in Government a few years back were more liberal than most private plans. Presently, annual paid vacations are based on length of service, i.e. 2 hours per week up to three years service, 3 hours per week from three to fifteen years service, 4 hours per week for over fifteen years. Sick leave accrues at rate of 2 hours per week regardless of length of service and can be accumulated year after year of Federal Service. The retirement plan is generally considered to be somewhat better than most private plans. Six and one half percent of gross earnings is deducted for retirement fund. The group life insurance is as good as most private plans. The Federal Government has an incentive award system that pays cash awards to accepted suggestions submitted by employees. Medical and hospital insurance is nonexistent at this time. It is expected that future legislation for the inclusion of some form of hospitalization in the benefit package will be provided.

Last year the travel stipend (per diem) was increased to a maximum of twelve dollars per day. Other increased benefits now being considered are larger payments of relocation costs when employees are transferred in the in-

terest of Government and payment of expenses for attendance at technical symposiums.

Conservation of Technical Manpower

An important phase of the technical studies involving the economical use of engineers is a part of the manpower utilization investigations. The manpower problem is one that is close to the heart of the Industrial Engineer and is one in which the Industrial Engineer will perform an increasing part in the near future. It has been stated that a ten percent improvement in the use of technical and scientific personnel nationwide would more than equal the number of engineering graduates from the nation's universities for the year. Within the Federal Government it involves the assignment of administrative and subprofessional duties insofar as possible to nonprofessional personnel. Paradoxically, the engineer in Government has proved that as an administrator he is often amazingly proficent. The habit of applying analytical thinking to administrative problems as he does to technical problems, obtains results. The Civil Service Commission is developing a policy of establishing Government wide criteria in the employment of engineers so as to contribute to the maximum productivity of technical personnel. This has not yet been fully implemented in practice but much is to be expected.

Many private firms consider Government experience to be an asset. The rate of turnover of Government engineers supports this attitude.

Job Satisfaction

To the engineer a feeling of satisfaction toward his work is of extreme importance. How many promising engineers have left Government and private employment because they felt a lack of good administration, proper supervision, pleasant work environment, challenging projects, stimulating associates, room for growth and advancement, and personal recognition, will never be known? The important thing is that Government is beginning to recognize these aspects of job satisfaction to a degree never before considered. The Cordiner Committee investigations on attitudes in Federal Government have shown that equipment, facilities, the caliber of associates, and fringe benefits, are generally thought of as favorable in Government. The technical employee feels that training opportunities are limited.

Recruitment of Engineers

The Civil Service Commission has authorized new approaches to the problem of attracting engineers to Federal Service without depending wholly on the salary angle. On the spot appointments can be made by agency egineers acting as recruiters. Credit in examinations is given for licenses, honors, membership in professional societies, and for other evidences of professional attainment. Faster than usual promotions can be had by outstanding candidates and trainees for engineering positions. The number of supergrades in engineering and scientific high level positions have been increased. Entrance salaries can be above the minimum established for a grade. Student training programs have been established. Credit for and time contributions have been made by Government agencies to encourage employees to take extra training outside Government. Government cannot compare equally with private industry nor can industry compare equally with Government in the matter of advantages offered to engineers. The two have separate and distinct fields of endeavor and functions to perform.

A bathelor's degree from an accredited college or university or technical experience equivalent to a four year college curriculum qualifies the applicant engineer for appointment in Grade GS-5 at $4,480 per year. Completion of a master's degree or six months professional engineering experience is required for appointment to GS-7, $5,335 per year. Advancement to GS-9, $6,115 per year is possible after eighteen months service. After a year in GS-9 engineers are eligible for promotion to GS-11, $7,035 per year. An additional year can bring promotion to GS-12, $7,570 per year. Above minimum grade starting salaries are not available in all positions. Advancement is not automatic. It depends upon experience, increased responsibilities, and the *occurrence of vacancies*. Within grade increases range from $125 annually after 52 weeks service to $215 annually after 78 weeks service. Job restoration rights are in effect after military service.

How to Apply

Positions are filled by evaluation examinations based on experience listed by the applicant. Written tests may not be required. Examinations are continuous and may be taken at any time. Separate examinations for engineering positions may be announced by the central or regional offices of the Civil Service Commission or by boards of United States Civil Service examiners located in Federal agencies throughout the United States. Application blanks can be obtained from Post Offices, Civil Service Commission, and Regional Offices.

Creation of Engineering Positions

When a position within a Government agency indicates the need for an Industrial Engineer to perform the listed duties, the agency Classification Officer assigned to the agency personnel office assists the department head in preparing a job description. The classification and grade level of the position is set by reference to job standards as established by the Standards Division, Bureau of Programs and Standards, Civil Service Commission, Washington 25, D. C. Assistance of the Civil Service Regional Office may be requested if the job is new or suitable general description of duties does not exist. The Regional Office may also refer to the Civil Service Commission for assistance in establishing classes and grade of a new position. Some agencies apply directly to the Civil Service Commission for assistance in filling specific positions.

Administrative criteria consistent with the laws ratified by Congress and affecting employment of Engineers are developed in the Natural Science, Engineering and Legal Section, Staff and Policy Group, Civil Service Commission. The Civil Service Regional Offices maintain lists of eligibles by engineering job title registers. Names of successful applicants are added to these lists. Agencies select prospective Engineers from the lists. When the position is urgent and in the absence of eligibles through exhaustion of registers, positions may be filled by the agency directly hiring the employee on a temporary indefinite status. The employee has the opportunity of gaining permanent status by taking the specific job examination when it is given.

The Civil Service Commission decentralized as far as possible the hiring of personnel for vacancies to the agencies. The Regional Offices administer and grade the examinations. Successful applicants are listed in order of their examination grades on the registers. The Natural Science, Engineering and Legal Section, Civil Service Commission recently completed general descriptions for Mechanical and Chemical Engineers. At this time a comprehensive description is being prepared for Electrical Engineers. It is planned that all categories of the engineering profession will be the subject of general job descriptions to be prepared by the Civil Service Commission in the near future. Agencies and Regional Offices are subject to periodic field checks performed by teams from the Civil Service Commission to insure adherence to class and grade limitations as established by law.

Industrial Engineering has been assigned the group and series classification number GS-896. Engineers were formerly listed as professionals with the prefix letter P as a part of the group classification number. Excessive restrictions experienced in hiring professional personnel for this classification caused its elimination shortly before the Korean War. The letters GS for General Schedule were substituted therefor. Hourly paid employees have the prefix WB, i.e. Wage Board, before their group classification number.

The Government Industrial Engineer on the Job

The increasing complexity of Government has caused a corresponding increase in the cost of Government. The economy of Government is subject to intense and critical scrutiny by the citizens and political interests. Instances of Government extravagances are given the maximum treatment in editorial comment. The findings of various committees for investigation of economy in Government during the past decade have recommended the application of the principles of Industrial Engineering although sometimes unknowingly. The Industrial Engineer is beginning to be recognized by Government and is being introduced into the management staff of larger Government installations. Specifically, the Industrial Engineer is being used in a variety of Government jobs allied with industry and industrial processes. It is understandable that Government in the past has not foreseen the advantages of applying the principles of Industrial Engineering to administrative processes. Since the beginning of World War II the conservation of manpower, materials, power, and time became a vital factor in achieving military and economic victory. For the first time the national effort was forced into the application of every measure that could produce a saving of resources. In the period after World War II a continued need for the coordinated conservation of resources was felt by Government. The principles of Industrial Engineering as applied by the trained professional Industrial Engineer was the obvious answer.

In the Department of Defense, the Army, Navy, and Air Force have many functions that are closely related to industrial processes. All have repair and maintenance depots where their basic arms are overhauled, modified, and tested. All have material storage and issue problems beyond anything experienced in private industry. All are subject to overnight expansion in immense proportions. Timely sufficiency of supply is their watchword. Here the Industrial Engineering principles can produce the greatest results. A few of the Government positions in which Industrial Engineers flourish are listed as follows:

Industrial Engineers (per se) Depot repair and maintenance establishing process lines, plant layout, standards, incentives, equipment, etc. GS 9 through 13.

Organization and Methods Examiners GS 5 through 11. This work is usually a part of the Personnel Administration Offices of posts, depots or is under the direction of the Comptroller as a device for appropriations control of expenditures and includes time study, production, work space layout, and classification. Some incumbents have found these positions elemental in scope.

Quality Control and Inspection Specialists Wage Board and GS 5 to 12. Quality Control at contractor's plants and maintenance depots.

Production Specialists GS 9 to 12. Maintaining rate of production in contractor's plants and is the source of diversified experience for the Industrial Engineer. Production delays are investigated from all angles. The Industrial Engineer fits in well.

Industrial Specialists GS 9 to 13. Work on higher plane than Production Specialist in industrial surveys from potential capability viewpoint.

Operations Analysts Usually in higher grades with policy making staff of Government agencies. Similar to Organization and Methods Examiners in lower grades. Not open to Industrial Engineers as frequently as to persons with administrative background and experience in Government. Industrial Engineering principles would benefit these positions.

General Engineer GS 5 to 13. More administrative than technical knowledge required. Difficult to define because the title in different areas is not equally descriptive.

Management Analysts GS 5 to 11. Evaluation and control of management problems. The Industrial Engineer who is interested in administrative management will gain practical experience here.

Occupational Research Analyst GS 9 to 12. Describing elements of duties for occupational areas, preparing job descriptions. Classification experience helpful.

Position Classifier GS 9 to 11. Classification of personnel by grade and job area, analysis of job elements.

Cost Accountant and Analyst GS 7 to 13. Segregation of industrial costs, and preparation of cost analysis reports. A background of cost accounting and knowledge of industrial costs categories is

necessary. An understanding of industrial processes is an asset here.

Maintenance Engineer—GS 7 to 11. Not janitorial. Occurs in military depots and is similar to Plant Engineer in charge of maintenance.

There are also many categories of positions open to the Industrial Engineer in the basic sciences, drafting, tool design, etc. The jobs listed occur frequently in all branches of the Department of Defense, some in the Post Office Department, many in the Atomic Energy Commission, the Department of Interior and other non-military agencies. A lesser number of positions are open to the Industrial Engineer in the Department of Labor and some of the older departments.

Civil Service employees are subject to the same attitudes and phobias that are experienced by their commercial counterparts. He is little different basically from his brother in private industry. Government is more sensitive to the attitudes of the people than private enterprise. In some areas the principles of Industrial Engineering have been accepted with limited enthusiasm by Government. At one time the use of the stop watch as an aid to the measurement of work was prohibited by law. This concept persists and seems to vary inversely with the size of the agency as measured by the amount of annual appropriation and publicity given the economy of the agency. Suspicion of new methods to effect economy has carried over from the days when drastic and uncontrolled methods were applied to show immediate savings in industry. The Industrial Engineer in Government service can help to advance a more positive acceptance of the principles by his exemplary performance according to the standards advocated by his professional society. Where traditional management practices are still used the more difficult is the job of the Industrial Engineer in Government as in private industry. The professional Engineer will face up to the problem and prove by his contributions to the job that the principles need not be a source of suspicion and distrust. Few bosses can resist an employee who performs his job so as to reflect credit back to the boss.

In the Department of Defense the Industrial Engineer is often under military supervision. It is the policy of the military to control their respective departments by use of military supervisors trained to be generalists rather than specialists. In the majority of instances this arrangement works well. It is not unusual to find Civil Service employees of advanced years and long experience in technical specialties reporting directly to a military supervisor who is a Second Lieutenant fresh from college. It need not be stated that this situation is conducive to many problems in personnel management.

The Military Industrial Engineer

Industrial Engineering training may be used to advantage in several job areas of the Departments of Defense military organization. One requirement lists Production and Procurement Staff Officer in grade of Major through Colonel. Among the prerequisites are noted Industrial Engineering or Business Administration training. Production Officer and Quality Control Officer lists Industrial Engineering or Business Administration training preference also. Grades for this latter group vary from Lieutenant to Major. Contract negotiation and administration as well as readjustment and termination activities use Procurement Officers of many categories. Legal as well as industrial background is an asset in some of these positions. Grades vary from lieutenant upward with duties commensurate with rank varying considerably.

The Industrial Engineer can contribute in the field of military intelligence where industrial processes or resources are to be evaluated or analyzed or survey of captured materiel is necessary. In the armaments field and in addition to the depot repair specialties the experienced Industrial Engineer can contribute as Armament Systems Officer. Maintenance Engineering specialties such as Maintenance Officer, Production and Control Officer, Fabrication and Repair Officer, Equipment Maintenance Staff Officer, and Ground Equipment Maintenance Officer, in grades from Lieutenant through field grades are closely related to the work of the Industrial Engineer. Base Installation Officer or Engineer can also be listed. Transportation Officer in allied fields of maintenance and scheduling is related to Industrial Engineering. Other general positions in commissioned grades that have been and are being filled by Industrial Engineers are:

Supply	Research and Development
Supply Staff	Human Resources
Budget	Military Attache
Special Investigation	Manpower Management
Statistical Services	Safety
Administrative	Education and Training
Personnel	

In addition to the foregoing and as attested by the historical records maintained in the files of National Headquarters, American Institute of Industrial Engineers, Industrial Engineers are a prime source of combat leaders.

The Military Industrial Engineer as a Supervisor

In principle the military supervisor need not be wholly expert in the technical aspects of his organization where specialists can be employed. In practice the military supervisor does a better job if he becomes a specialist as well as a generalist. The more aware he is of the technical side of his responsibility the more economy is engendered into the product of his organization. The military supervisor administers with a minimum of personal technical contribution and a maximum of administrative coordination effort. A military supervisor who is a good administrator but lacking technical ability will succeed where a good technically trained military supervisor who lacks administrative ability will fail. Military supervisors having a background in Industrial Engineering serve in various grades and responsibilities in the following general areas:

Military Depots—Current military thinking proposes a supported military effort for a relatively short duration in execution of defense plans if need arises. Increased use of machine weapons including mechanized transportation and electronic devices creates immense logistical problems. Coordination of obsolescence, space, timely use, packaging, receipt and issue, is being resolved into a science to which the Industrial Engineer can contribute his professional skill. This problem is common to all departments of defense.

Military Modification and Repair Depots—When military equipment is overhauled or repaired at a depot often the operations are closely allied to commercial job shop manufacturing. The difficulties of process, materials handling, quality, equipment use, training of personnel, are similar to those encountered in private industry. This is a natural field of employment of the Industrial Engineer. The Manpower, Personnel, and Reserve Section, Office of Secretary of Defense, recognizes this similarity and has actively supported the application of industrial practices in these areas.

Military Procurement—The Industrial Engineer who is familiar with contract law, costs accounting, materials, processes, buying, etc., can produce many economies in the field of contract administration, production control, quality control, etc.

Military Base Maintenance—An awareness of the military in planning maintenance patterned after commercial industrial practices has further increased the opportunities of the Industrial Engineer particularly in the layout of facilities. Operations are not as extensive as depot technical maintenance.

Military Administration—Here is an untouched area common to all defense departments waiting for the Industrial Engineer to apply the principles of economy. It is not meant that wastefulness prevails throughout Government or that agencies are by nature incapable of economy of effort. The swiftly fluctuating defense plans, weapons concepts, and potential aggressor capabilities are coordinated in an outstanding manner by the Departments of Defense. The Industrial Engineer can contribute to administrative process planning on policy level.

Conclusions

The following conclusions are presented for your consideration:

1. There is a definite upswing in the awareness of Government agencies to economies that can be effected by the Industrial Engineer.

2. The use and understanding of the Industrial Engineer in Government is hampered by a partial misunderstanding as to how the Industrial Engineer can be used to best advantage. Lack of definition of what an Industrial Engineer is and does, contributes to this concept.

3. There exists some reluctance to adopt and apply the principles of Industrial Engineering which is apparently based on early prejudices.

4. The Civil Service Commission and military departments are doing everything in their power to insure that all categories of Government engineers meet minimum professional standards of training and experience as generally accepted in the profession. In those isolated instances where persons have been enrolled as engineers who were not qualified, corrective procedures have been applied.

5. The use of Industrial Engineers in Government is unnecessarily limited to those areas that are considered to be comparable to industrial type operations.

6. The Post Office Department is making the greatest use of Industrial Engineers. The Department of Army has the most active Industrial Engineering program in the Departments of Defense.

7. The Departments of Defense recognize Industrial Engineering training but do not insist that it is the only acceptable prerequisite for positions closely allied with the Industrial Engineering concept.

Recommendations

The following recommendations are presented for your consideration:

1. An attempt should be made to more completely identify the Industrial Engineer and his field of logical endeavor by definition both general and specific.

2. The Civil Service Commission and the Department of Defense should be coordinated regularly by notices of activity engaged in by the American Institute of Industrial Engineers to uplift the profession of Industrial Engineering and to suggest the advantages that can be realized through employment of Industrial Engineers.

3. Each instance of relaxation of professional engineering standards in Government should be frankly discussed with the Civil Service Commission and the Departments of Defense, or other Government agencies.

4. National Headquarters, American Institute of Industrial Engineers, should maintain a file of recent data pertaining to general job descriptions, standards of experience and training, classification of positions, wage and salary studies, relating to the profession and to be supplied to interested parties and agencies upon request.

5. Each professional Industrial Engineer and particularly those in Government service can aid in the acceptance of the Industrial Engineering profession by continuing the practice of the profession to the best of his individual capabilities. The professionally qualified Industrial Engineer of unquestioned ability and integrity is the best advertisement of the standards of this profession. Acceptance of the Industrial Engineering principles will stem from the success of the capable Industrial Engineer in practice whether in Government or private industry.

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Industrial Engineering

AND

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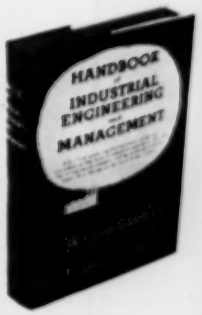

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Report on the Eighth Annual Conference of the AIIE

By A. J. Asalone

Industrial Engineer, Western Electric Company, Kearny, New Jersey

Anxious members of the Convention Council stopped at the registration desk of the AIIE's 8th Annual National Conference throughout the day on May 16th and 17th. How was registration coming? Would the conference break even? Would it be a success? When the final results were known, there were smiles of relief and pleasure. The Conference attracted 1128 people. It was the largest AIIE meeting to date. It made a net profit of $10,000, more than any other meeting up to this time.

This end result was the product of more than a year and a half of planning and hard work by Convention Council members. It was the end result of the generous cooperation of the newspapers, magazines, and radio programs that passed the word that New York City was to be the meeting place of the Eighth Annual Conference. It was the result of a proclamation by Mayor Robert Wagner that made May 13 to 18 "Industrial Engineering Week." It was also the result of the City renaming famous "Times Square" as "Industrial Engineering Square."

The Conference, which was opened by Henry M. Owades, President of the Metropolitan New York Chapter, got under way with a stimulating keynote address by the author and consultant Peter Drucker. Following this for the next two days registrants listened to lectures, participated in seminars and watched motion pictures on topics ranging from operations research to work simplification.

A questionnaire was circulated to determine the most popular subjects covered at the meeting. The small group seminar discussions led the list. Subjects of special interest were: operations research, management controls, statistics and mathematics, plant layout, material handling, budgetary and cost control, work simplification and measurement and production planning and control.

Field trips of special interest to Industrial Engineers opened areas not usually visited by the public at well known locations. The Port of New York Authority, the General Post Office, Bush Terminal Buildings and the New York Stock Exchange were all visited.

A ladies program ran concurrently with the Convention and included a fashion show, a trip to the United Nations, and attendance at the Thursday evening banquet.

The Thursday evening banquet was one of the high spots of the Convention. Presiding was Howard P. Emerson, now Past National President of the Institute. Alex W. Rathe, Associate Professor of Management Engineering, New York University was toastmaster. The first order of business was the "Award of Honors" to Dr. Lillian Gilbreth to commemorate her previously presented Fellowship. This gift was accepted by Ernestine Gilbreth Carey in the absence of her mother who was in Europe. Fellowships were awarded to David B. Porter, Professor of Industrial Engineering, New York University and Frank H. Neely, Chairman of the Board, Rich's, Inc., Atlanta, Georgia. Following the awards, the guest speaker of the evening was introduced; N. E. Felt, Jr., Operations Manager Earth Satellite Project, Glenn L. Martin Co. He spoke on the earth satellite project, describing the launching of the earth satellite.

"Times Square" becomes "Industrial Engineering Square" for the week of May 15th. Miss Betty Mancuso changes the sign.

On Thursday noon, Kenneth McFarland, sponsored by the General Motors Corporation, presented a luncheon speech entitled "Ropes of Gold." He dealt mainly with the reasons behind success and failure. At the Friday luncheon, a speech on "American Know-Why" was presented by Dwayne Orton, Editor of *Think*, Educational Consultant, International Business Machines Corporation, and President, Council for International Progress in Management.

A closed circuit television program reviewing the Industrial Engineering scene today was the final Friday session. The program was moderated by Chet Huntley, the nationally known news analyst.

The reviews were separated into sections dealing with the various aspects of Industrial Engineering.

Section I, "Industrial Engineering Pioneers", was led by Dr. L. W. Wallace, Conference Leader, Ordnance Management Engineering Training Program, Rock Island Arsenal. The participants were John Willard, Partner, Bigelow, Kent and Willard, and A. M. Lederer, President, Morris and Van Wormer. It dealt with the great Industrial Engineering leaders, their accomplishments, and with the accomplishments of the Industrial Engineers as a group.

Section II was titled, "The International Industrial Engineering Scene." The chairman, E. H. MacNiece, Technical Consultant, Permacel Tape Corporation, was joined in the discussion by Edward DeLuca, Vice President, Gardner Display Company and Jerome Barnum, President, Jerome Barnum Associates. The session dealt with the use of various Industrial Engineering techniques abroad, and developed a comparison of these techniques as used here and abroad.

"Beyond The Industrial Engineering Horizon" was the title of the third section. The chairman was Mrs. Gene Weeks of Gene Weeks and Associates. With her were Professor W. Richardson of Lehigh University and Dr. William Gomberg of Washington University. This session dealt with the various activities the Industrial Engineer may be called upon to perform in the future.

The final section, "Top Management Looks at Industrial Engineering", was led by Professor Alex Rathe and featured Harold Scherr, President, Juvenile Manufacturing Company and H. E. Chiles, Jr., President, The Western Company. This section presented an interesting commentary on the strengths and weaknesses of Industrial Engineering as some top management people saw them.

Mayor Robert Wagner presents the proclamation of "Industrial Engineering Week" to Professor Howard P. Emerson, Past President of AIIE, as Dean Gordon B. Carson, President of AIIE looks on.

The convention was closed by Frank M. Gryna, Jr., Conference Co-Chairman.

The Conference was, as measured by attendance and income, a success. But those who worked on it finished their work hoping that something more had been accomplished. They had seen the conference as an opportunity to advance the profession of Industrial Engineering. It was a chance to present both a showcase of Industrial Engineering interests for management and the public to see, and a stimulating and educating meeting for the Industrial Engineer. Figures alone cannot answer the question of whether these goals were realized, but there was a feeling of optimism in the air as the Conference ended.

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An Application of Linear Programming to the Assignment of Materials Handling Equipment

By Virgil Erickson

S. C. Johnson and Son, Inc.

and Paul H. Randolph*

Assistant Professor, Department of Industrial Engineering, Illinois Institute of Technology

In many companies, especially process industries, there are often several available methods for transporting material. Generally conveyors provide the most economical method of handling large quantities of material. However, conveyors lack the flexibility of fork lift trucks and pallets. Therefore, as a compromise between flexibility and cost, or for other reasons, a company may have developed a materials handling system which includes a variety of types of equipment.

If the company also has a wide variety of products, then the selection of the type of materials handling equipment for each product may become rather complex. An arbitrary assignment of materials handling equipment usually results in higher handling costs than a systematic assignment. In one company in the Chicago area, for example, a random selection of equipment would require a material handling crew of up to six men more than the crew size of the schedule found from linear programming.

Case Study

The principle is illustrated by the following case study of a glass company which produces a wide variety of bottles, tumblers, and a host of other glass products. These items are produced on a group of twelve machines, packed in corrugated cases and then carried away on twelve conveyor lines, one from each machine. Only one product is produced on a machine each work day, with new setups made by a special night shift. Thus, daily production is limited to twelve products.

The conveyor lines carry the various packaged products from the production locations to the shipping area where the cases are either palletized manually, palletized automatically, or are conveyorized directly into railroad cars. Thus, there are three methods of handling the product. The semi automatic palletizer (4) (5) is a devise with a power lift platform which lowers the pallet as the cases are fed onto the platform. Thus the operator can slide the corrugated cases into position with little effort. In manual palletizing the cases are lifted manually from the conveyor to a pallet placed on the floor. Because the size of the crews assigned to manual palletizing can be varied at will, all products that are not conveyorized or palletized automatically are placed on pallets by hand. When carloading by conveyors, the cases are fed through a conveyor switching station. This station directs the various products to the proper railroad car, where they are loaded manually into the car from the conveyor.

Since the total number of products manufactured by this company is considerably more than the daily limit of twelve, the various combinations of products produced is different each day and each day a new decision must be made as to how the combination of twelve products will be handled. These decisions must be made within the framework of the restrictions of the company. Let us consider the restrictions of the company of this case study.

Both methods of palletizing require subsequent handling by fork lift truck to bring the material to a railroad car, to the truck dock or to the warehouse. The conveyors

TABLE 1

Man Hours and Daily Production Rates For All Products

Product	Man Hours Required per 100,000 lbs.			Daily Production (Thousands of Pounds)
	Conveyer	Automatic Palletizing	Manual Palletizing	
1	26	31	37	112
2	27	29	37	164
3	25	28	37	181
4	56	81	70	21
5	32	62	88	65
6	26	31	37	110
7	29	32	37	96
8	28	31	37	117
9	49	60	70	43
10	35	38	42	70
11	57	62	68	36
12	33	37	42	76

* Presently Associate Professor, Industrial Engineering, Purdue University.

TABLE 2

Cost Table For Transportation Calculations

Product	Man Hours Required per 100,000 lbs.			Daily Production (Thousands of Pounds)
	Conveyor	Automatic Palletizing	Manual Palletizing	
1	26	31	37	112
2	27	29	37	164
3	M*	28	37	181
4	56	81	70	21
5	32	62	88	65
6A	26	31	37	50
6B	M*	31	37	60
7	M*	32	37	96
8	28	31	37	117
9A	49	60	70	10
9B	M*	60	70	33
10	35	38	42	70
11	M*	46	42	42
12	M*	37	42	76
	250	277	570	1097

* A cost value which is large enough to prevent conveyor handling for this product.

can transport the material only to the freight cars. Some products may not be shipped by rail and therefore require handling by pallets. Thus, only a solution which assigns no units to the conveyor for these products can be permitted. This can be accomplished by assigning a very high cost to the transportation of these products by conveyors.

It is also possible that only a part of the daily production of a product will be shipped by rail with the remainder taken to the truck dock or to storage by fork truck. In this case the product can be considered as made up of two sub-products with the total daily production split among these two sub-products. One of these sub-products will be assigned a daily production equal to the amount to be shipped that day with the normal conveyor cost. The other sub-product will have a daily production equal to the remainder but with a large conveyor cost.

Conveyor loading is limited to a total of five carloads of 50,000 pounds each, or a total of 250,000 pounds. Since there are three automatic palletizers, the total capacity of the automatic palletizer is approximately 25% (3 lines out of 12) of the total daily production. The manual pallet system is unlimited in capacity.

Cost of Handling

The cost of handling the material is directly related to the number of labor hours required, which in turn has been found to be linearly related to the number of pounds handled. That is, the cost of handling 1,000 pounds is 5 times the cost of handling 200 pounds. This company has collected information on the number of man-hours per 100,000 pounds required for handling each product on each type of materials handling equipment.

Let us consider a typical day with twelve products. In Table 1 the cost characteristics in man hours and the daily production rates of these twelve products are given. Four of these products, those numbered 3, 7, 11, and 12, are not to be shipped that day, and therefore the conveyor cost of these products must be made large enough to prevent conveyorizing. This is indicated by a cost of "M" in Table 2, where M is as large as we wish to make it. Furthermore, only 50,000 pounds of product 6 and 10,000 pounds of product 9 are to be shipped by rail. Therefore, these two products are each considered as made up to two sub-products designated by A and B. Sub-products 6A and 9A are assigned a daily production of 50,000 pounds and 10,000 pounds, respectively with normal conveyor cost, while sub-products 6B and 9B are assigned the remainder of the daily production with a high conveyor cost, as shown in Table 2.

Since conveyors generally require less man hours than either method of palletizing, the total capacity of the conveyors, namely 250,000 pounds will be used. Likewise, the automatic palletizing uses less man hours than manual palletizing for most products and thus these will also be used to their capacity of 25 per cent of the daily total production, or 277,000 pounds. The remaining 570,000 pounds will be handled manually. These capacity restrictions are noted at the bottom of Table 2.

Method of Handling

With Table 2 the problem of assigning the materials handling equipment to the products can be solved quite easily by the well known transportation algorithm of linear programming. Since this computational method has been explained many times in other articles (1) (2) (3), it need not be repeated here. The linear programming solution is given by Table 3. This table implies that all 112,000 pounds

TABLE 3

Linear Programming Solution of the Materials Handling Selection Problem

Product	Thousands of Pounds Handled			
	Conveyor	Automatic Palletizing	Manual Palletizing	Production
1	112			
2		63	101	112
3		181		164
4	21			181
5	65			21
6A	42		8	65
6B			60	50
7			96	60
8			117	96
9A	10			117
9B		33		10
10			70	33
11			42	70
12			76	42
				76
Total	250	277	570	1097

TABLE 4

Modified Solution of the Materials Handling Selection Problem

Product	Thousands of Pounds Handled			
	Conveyor	Automatic Palletizing	Manual Palletizing	Daily Production
1	112			112
2		164		164
3		181		181
4	21			21
5	65			65
6A	50			50
6B			60	60
7			96	96
8			117	117
9A	10			10
9B		33		33
10			70	70
11			42	42
12			76	76
Total	258	378	401	

of product 1 will be handled by the conveyor; 63,000 pounds of product 2 will be handled by the automatic palletizer and 101,000 pounds by manual palletizing; and so forth. This is the minimum cost solution which satisfies the stated capacity and production requirements. No other program will involve less total cost.

Although this is the minimum cost solution satisfying the specified requirements, it is not necessarily the one to follow. For example, consider the total of 277,000 pounds to be assigned to the automatic palletizer. This figure is arbitrary, based on the fact that the company has three automatic palletizers which can be assigned to serve any three production lines. The assignment of product 2 to two methods of handling implies that one of the automatic palletizers will be idle part of the day, which seems unreasonable. Thus, rather than split product 2 into two methods of handling, all of this product could be assigned to the automatic palletizers at a saving of approximately one man day ($.08 \times 101 = 8.08$ man-hours) for the day. This, of course, increases the rather arbitrary marginal requirement of the automatic palletizer to 378,000 pounds. Likewise, since box car loads can be varied slightly, it may be desirable to investigate the possibility that all of product 6A be transported to the boxcars by conveyor. This would save about half a man hour ($.05 \times 8 = .40$) per day.

These two changes are given in the modified schedule of Table 4. With these changes in equipment requirements, we no longer have the original problem and thus the modified solution is not necessarily optimal. However, the transportation algorithm can be applied to the new model to test the optimality of this modified solution. Normally this modified solution is degenerate but the usual rules for degeneracy can be followed. In this case study the modified solution was found to be an optimal solution, as is usually the case.

Thus the final minimal cost solution is to handle all of product 1 on the conveyor, all of product 2 on the automatic palletizer, all of product 3 on the automatic palletizer, all of product 4 on the conveyor, etc.

Conclusions

The problem of this case study is similar to that found in many plants. Current practice is to assign the products to equipment rather arbitrarily. This procedure is inefficient and chancy and does not guarantee a minimum cost schedule. In contrast, the application of linear programming assures a minimum cost solution and provides a procedure which is so simple that the scheduling can be assigned to clerks.

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Predetermined Time Standards for Variable Set-ups

By D. A. Drewery[1]

Chief Industrial Engineer, P. & H. Harnischfeger Corporation, Milwaukee

and R. R. Coats[2]

Assistant to the Vice President of Manufacturing, H. C. Smith Oil Tool Company, Los Angeles

In a shop where a condition of small quantity production lots is the rule rather than the exception, the problem always exists as to the accuracy of labor standards for the set-up portion of the operation. This problem becomes magnified as the portion of an employee's time concerned with set-up operations increases, and the planning sequence of job assignment is dictated more by the urgency of the job rather than the similarity of jobs. The incentive worker wants the assurance that he is being paid for the work he performs. Management likewise wants the assurance that its labor costs are under control.

Labor standards for set-ups have been handled in many ways. The most satisfactory method used to date is the on-the-spot analysis of the work performed and, through the use of standard data or a stop watch, the necessary allowances made. This is costly in observer time and requires the operator to perform the work first and later be notified of his standard. This eventually leads to incomplete coverage, ineffective incentives, and employee dissatisfaction. The most common method is to allow a fixed and normalized set-up. This can result in penalty to either the company or the operator and is insensitive to changing methods and conditions. Still another method shifts the responsibility to the operating supervisor to negotiate a "price". All of these eventually lead to labor disputes for their obvious reasons.

The system to be outlined in this paper was developed in a job shop atmosphere. Crossed production lines of custom-engineered overhead cranes, power shovels and other heavy machinery require a fluid production schedule with endless changes in job scheduling. Aggravating this condition is a superimposed and very heavy repair order schedule with the usual "Rush", "Special Rush" and "Emergency Breakdown" categories. With the "breakins" and changing production demands, the need for a flexible yet sensitive set-up standards program is unquestioned. The company subscribes to a policy of maximum coverage with direct measuring incentive standards. Product costing is currently on an actual or "as incurred" basis. Elemental standard data and standard operating practices are the bases for all labor standards calculations.

To predetermine time standards for any operation, recognition of the work an operator must perform is all important. To do so for the set-up portion of the operation, the analyst must know the details of the set-up for the preceding operation. It is conceivable that with proper scheduling of work through a given work station, the set-up may require only a minor tooling change. Or again, despite planning, a major change may be necessary. There is still the question of whether the set-up operation will always require the same amount of work. Will the sequence of work flow always remain the same through each work station? When is the sequence, and thus the amount of work, known? Since sequence is very difficult to control, particularly in a job shop, recognition of the variable or conditional portion of a set-up, depending upon the preceding operation, is vitally important.

Under this predetermining standards system the set-up standard is actually developed in the following three stages, the first two being fixed for any particular job:

1. The job change portion, or that work which occurs in every set-up regardless of the particular job in question. Examples of this are receiving job assignment, studying blueprint, walking to and from dispatcher's station, etc.
2. The assignable job portion, or that work that depends upon the particular job assignment and is constant regardless of assignment sequence. This may include setting feeds and/or speeds, assembling certain holding devices, and placing and removing special cutting tools.
3. The conditional portion, or that work that is governed by the set up of the preceding job. This may consist of the possible usage of general purpose cutting tools, tool and material holding devices, etc., from the previous set up.

Conditional Set-up Standards

The explanation to follow will be primarily devoted to the development, administration and effect of the third stage since the first two are self-explanatory. The development of this third stage is outlined as follows:

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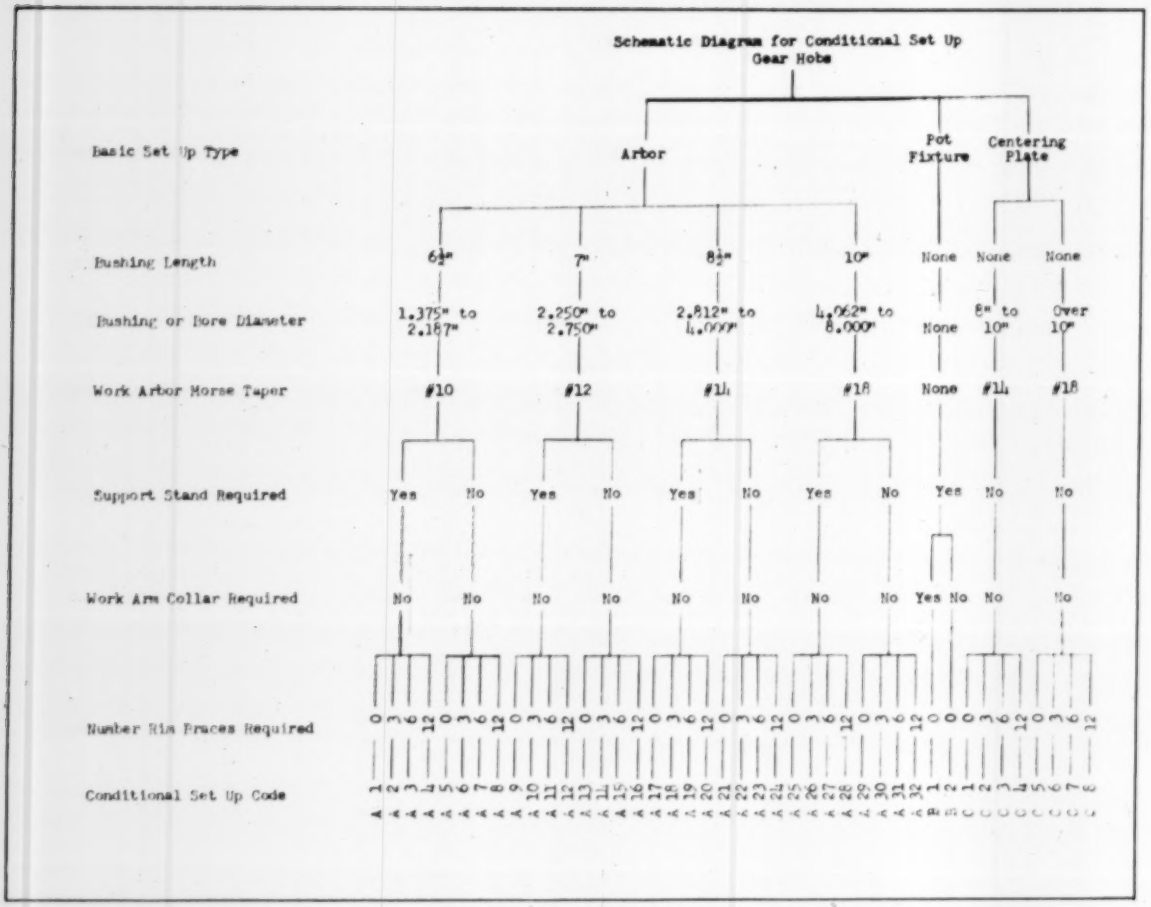


Fig. 1 Schematic Diagram

I. Schematic Diagram (Figure 1).
   A. Basic types of set-up.
   B. Components.
   C. Set-up coding.
II. Check Sheet Development (Figure 2).
   A. Elemental analysis.
   B. Calculation of standards (via machine tabulating equipment).
III. "Baseball Schedule" Chart of Set-up Time Values (Figure 4).

These exhibits are taken from the actual development of conditional set-up standards for gear hobbing machines. However, the same principle has been applied to a wide variety of machine tools, and can be further extended to any equipment or station where the sequence variable exists.

Where the set-up of a machine tool is completely made for every job, a complete fixed standard can be precalculated and in such cases conditional standards are impractical. We have found such to be true for upright drills, keyseaters, and fully automatic and special purpose machine tools.

I. *Schematic Diagram*

The important variables affecting the amount of set-up required in going from one job to another must be determined as the first prerequisite in setting up the schematic diagram. These variables represent the components of the basic set-up types. As an illustration of this analysis refer to Figure 1 "Schematic Diagram for Conditional Set-Up Gear Hobs". The first step is to determine the basic set-up types, which in this case reflects the method of holding the gear blank while hobbing the teeth. This resolves into three work methods: (A) Work Arbors, (B) Pot Fixtures, (C) Centering type face plates.

It is then found after further analysis that although one job held on a work arbor might be followed by another held on a work arbor, the arbor quite possibly would have to be changed because of the length of bushing required, the bushing or bore diameter, or the morse taper

on the arbor. These three variables are classified from standard categories and plotted as legs on the schematic diagram under the basic set-up type "arbor". The next consideration to be made is simply a "yes" or "no" requirement of the support stand or work arm collar. This adds two legs to each of the four previously described. The final item which seems to affect time from one set-up to the next is the use and the quantity of rim braces used in supporting the gear blank. This is standardized as to the quantity to be used dependent upon the outside diameter of the gear blank and drawn as four additional legs to those previously described. The same sort of analysis is then pursued in the extension of the diagram for each of the other two basic types of set-ups. The three basic set-up types are then coded as follows: (A) Work Arbors, (B) Pot Fixture, (C) Centering plate, and each leg of the schematic diagram is numbered consecutively through all the legs for each basic set-up type.

II. *Check Sheet Development*

The next step is the development of a check sheet (Figure 2) for determination of time requirements to perform the various operations in going from one basic type of set-up to another. The time values used on the check sheet must reflect separate times for "place" and "remove" of the variable components of the set-up since the work will be performed at different times and possibly by different operators. Each element or operation of work is numbered and listed separately with the time values required to perform same. Space is provided for the analysis from one basic set-up type to another.

A. Check sheet analysis to determine time values.

The analyst determines the ultimate time required to perform the conditions of the set-up by using the schematic diagram (Figure 1) and the check sheet (Figure 2). He traces from the end of one leg to the end of another following the schematic diagram and the shortest possible path. As this is done the necessary elements are checked off in the appropriate block.

Example: From set-up type A28 to set-up type C2.

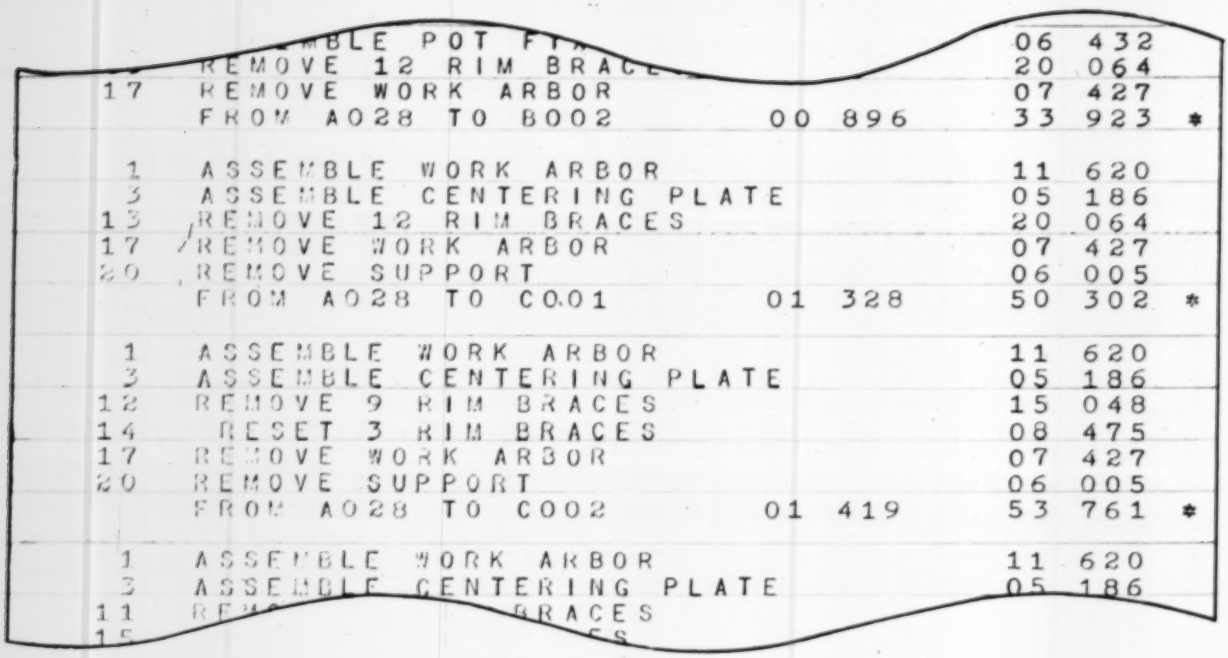
Set-up A28 is a basic arbor type using a #18 taper work arbor, a support stand and 12 rim braces. Set-up C2 is a centering plate basic set-up requiring a #14 taper work arbor and 3 rim braces. To go

Operation Analysis
Conditional Set Up Standards
(Based on One Machine Assignment)
Gear Hobbers

From Set Up Type A 2 3 Date: 3/3/52 To Set Up Type Prepared By: R R Last

	Normal Time/Occ.	B1	B2	C1	C2	C3	C4	C5	C6	C7	C8
1. Assemble Work Arbor	11.620			1	1	1	1				
2. Assemble Pot Fixture	6.432	2	2								
3. Assemble Centering Plate	5.186			3	3	3	3	3	3	3	3
4. Assemble Support Stand	6.553										
5. Assemble Work Arm Collar	4.458	5									
6. Assemble 3 Rim Braces	8.109										
7. Assemble 6 Rim Braces	16.218										
8. Assemble 9 Rim Braces	24.327										
9. Assemble 12 Rim Braces	32.436										
10. Remove 3 Rim Braces	5.016										
11. Remove 6 Rim Braces	10.032					11				11	
12. Remove 9 Rim Braces	15.048				12				12		
13. Remove 12 Rim Braces	20.064	13	13	13				13			
14. Reset 3 Rim Braces	8.475				14				14		
15. Reset 6 Rim Braces	16.950					15				15	
16. Reset 12 Rim Braces	33.300						16				16
17. Remove Work Arbor	7.427	17	17	17	17	17	17				
18. Remove Pot Fixture	7.231										
19. Remove Centering Plate	5.605										
20. Remove Support	6.005			20	20	20	20	20	20	20	20
21. Remove Work Arm Collar	4.166										
TOTAL MINUTES											
Std. Hrs. Tot. Min. x .0264											

FIG. 2 Check Sheet



	[illegible] POT FIX			06 432	
	REMOVE 12 RIM BRACE[illegible]			20 064	
17	REMOVE WORK ARBOR			07 427	
	FROM A028 TO B002	00	896	33 923	*
1	ASSEMBLE WORK ARBOR			11 620	
3	ASSEMBLE CENTERING PLATE			05 186	
13	REMOVE 12 RIM BRACES			20 064	
17	REMOVE WORK ARBOR			07 427	
20	REMOVE SUPPORT			06 005	
	FROM A028 TO C001	01	328	50 302	*
1	ASSEMBLE WORK ARBOR			11 620	
3	ASSEMBLE CENTERING PLATE			05 186	
12	REMOVE 9 RIM BRACES			15 048	
14	RESET 3 RIM BRACES			08 475	
17	REMOVE WORK ARBOR			07 427	
20	REMOVE SUPPORT			06 005	
	FROM A028 TO C002	01	419	53 761	*
1	ASSEMBLE WORK ARBOR			11 620	
3	ASSEMBLE CENTERING PLATE			05 186	
11	REM[illegible] BRACES				
15	[illegible]				

FIG. 3 Tabulation of Standards Calculations

from an A28 type set-up to a C2 type the operator must remove 9 rim braces, and reset 3. Elements numbered 12 and 14 are appropriately checked. Tracing up the legs of the schematic diagram, the work arm collar is not required in either type of set-up. The support stand is required in the A28 set-up and must be removed for the C2 set-up. Element number 20 is entered into the proper block. The #18 work arbor used for the A28 set-up must be replaced by a #14 work arbor for C2. Element numbers 17 and 1 are entered. The only thing left in the conditional change over is to assemble the centering plate. Element number 3 is entered.

B. Calculation of Standards.

The conditional portion of the set-up operation for gear hobs requires 1764 calculations. On other machine tools this figure may be substantially higher. Utilization of machine tabulating equipment to perform this calculation operation accurately and rapidly is a very practical solution. However, in order to do this some definite planning and direction is a must. First a master card deck is key punched from the check sheet (Figure 2) with each card representing an element of work and carrying the complete information shown on the check sheet by element number. From the master card deck duplicate cards are made through the duplicating machine. A blank tabulating card of a different color is then punched for each leg of the schematic diagram (Figure 1) reading from set-up to set-up, with this card reflecting, as an example, "From set-up A-28 to set-up C-2". With the calculation framework established the various cards are assembled for the calculation operation. This is done with clerical help. The duplicate cards of the master card file are placed in order by element number in an open top container and identified by use of index spacers. The clerk assembles the individual cards required for each leg of the conditional set-up by using the check sheet and collating the cards by number as shown in each column of the check sheet.

Example: From set-up A-28 to C-2.

Cards numbered 1, 3, 12, 14, 17 and 20 are assembled with the identifying set-up card "From set-up A-28 to set-up C-2".

As the assembled cards are accumulated they are fed into the tabulating machines where the normal minutes are totaled, calculated into standard hours based on the policy formula for allowances, and listed (Figure 3). The resultant allowed time is automatically punched to the identifying set-up card, and the identifying set-up card is then used for a summary listing.

III. *"Baseball Schedule"—Chart of Set-up Time Values (Figure 4).*

The time values required to perform the various combinations of the conditional set-up are now developed,

but they must be put in such form to be effectively utilized. One method of doing this is by the use of the so-called "Baseball Schedule". All of the values are put into tabular form so that by reading from the one axis "From set-up type-" across and down from the other axis "To set-up type-" the desired value is quickly obtained.

Where the number of variables exceeds those found in this gear hobbing example, it is frequently found convenient to create more than one schematic diagram and thus more than one chart. Such a device was employed for standards for turret lathe set-up operations. Because of the possible combinations, over 15,000,000 calculations would have been necessary to confine the plan to one single chart. However, by normalizing out the minor variables and employing four charts (two each for the hexagonal turret and head stock) the number of calculations was reduced to approximately 13,750.

Thus far then we have established a system whereby every possible type of machine set-up can be designated by a simple code number. We have likewise precalculated performance standards to be applied when an employee is required to change over a machine from one type of set-up to another. All that remains is to bring this information together at the right time and place.

Administration

As in many programs, the success of this one is dependent upon good administration. The following are essential requirements to put into being predetermined time standards for variable set-ups:

1. A staff of Industrial Engineers fully familiar with the available tooling and types of set-ups as applied to the company's products. Predetermined standards are of greatest value from the standpoint of incentive administration cost and incentive effect if they can be established as routings (or process sheets) developed in the office from new engineering drawings. Normal observation ability is all that is required for on the job studies while a highly experienced Industrial Engineer is required to pre establish operations analysis. The analyst in calculating the set up standard (a) establishes the fixed portion of the set up, (b) determines the set up coding, or the type of set up required to process the part, and (c) makes entry of (a) and (b) on the routing master.
2. A properly maintained master routing system. This system must be current at all times reflecting any changes in machine tools, jigs and fixtures and product engineering changes.
3. An order scheduling board with job assignment made by a dispatcher or shop clerk. With scheduling cards racked on the scheduling board in job sequence order, the dispatcher (a) determines the conditional set up code of the preceding job and the one to which the operator is being assigned; from A28 to C2 (b) determines the allowed time from the baseball schedule; 1.419 standard hours divided by 2 and (c) adds this conditional portion to the fixed portion as specified on the scheduling card; .442 + .710 = 1.152 standard hours. This total is entered on the operator's labor card at the time the job assignment is made.
4. Non scheduled auditing of shop clerk computations. Whenever human errors are possible, auditing of such programs

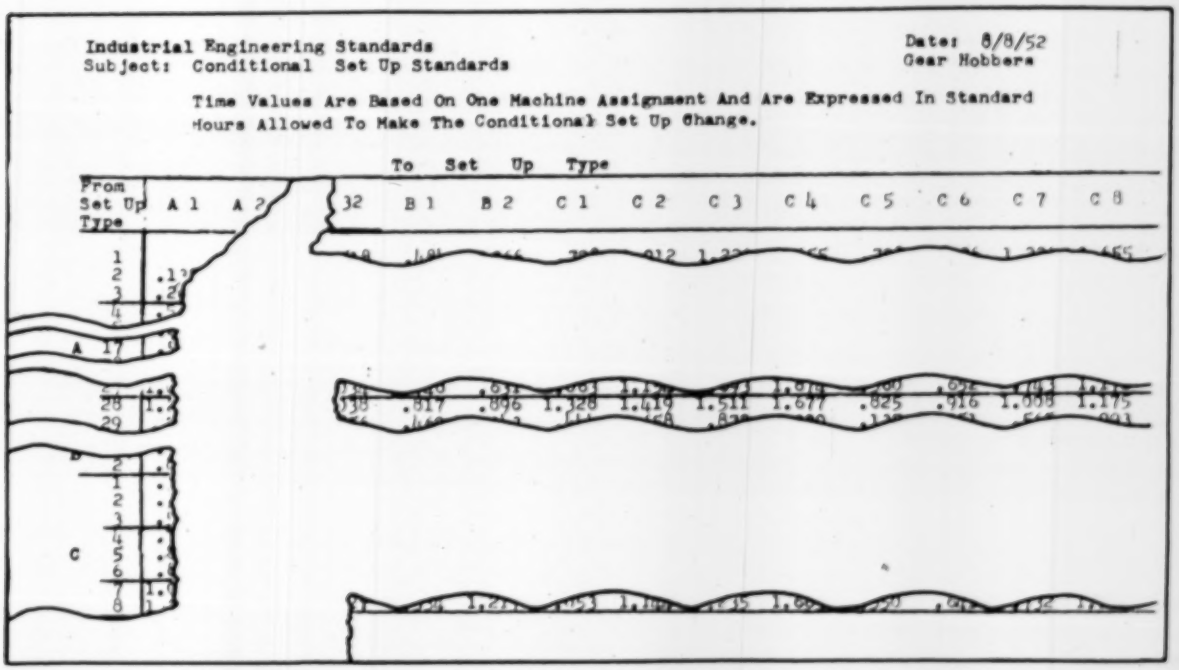


Fig. 4 Chart of Set-up Time Values

should be exercised. Typical audit summaries are made. Attention is given to the percent variance actual to standard. With minute negative variances the possibility of collusion and significant error can be dismissed. The audits also suggest the avenue of approach to a standard cost system or cost estimating. The average percentage of the conditional portion to the fixed portion of the set-up standard can be used to increase the latter figure.

Conclusion

The success of this system is best attested by the experience with it after being in effect for over two years.

1. No labor disputes have arisen as to the sequence of work assignment. If a foreman requires an operator to make a complete tear down and rebuild of the set-up due to poor planning, the operator is paid in proportion to the additional work required.
2. By being informed by the shop clerk of the size of the conditional set-up standard, the foreman can be checkmated and realign his production schedule for minimum labor costs and maximum production, all other production requirements being equal.
3. Since the operator does not stand to be penalized due to a normalized, fixed set-up, the size of the production runs has no bearing on his earnings. Thus, the foreman has no trouble expediting urgent small quantity repair orders across the various facilities.
4. The time to compute a total standard by a shop clerk is very small for each job, but there can be no denial that accumulatively for a full department a noticeable clerical work load is imposed. However, the total standard is computed before the job assignment is actually made eliminating delay on the part of direct labor. The heaviest such load is in the turret lathe department (three separate conditional standard figures per job) where in addition to this function the shop clerk performs all clerical duties including maintenance of the order scheduling board for approximately 46 turret lathe and related machine operators.
5. The system requires an investment of Industrial Engineering man hours at the outset. However, once the schematic diagrams and baseball schedules have been established, a substantial number of analytical man hours are saved thereafter since this much of a set up standard requires only a coding instead of an assembly of work elements. We currently develop new set up standards of this category for about 300 operations per week. An estimated 30 to 40 additional Industrial Engineering man hours would be required every week were the standards precalculated on a normalized, fixed basis. Or on another basis, the additional time of 6 to 10 observers would be required were the standards calculated on the floor on an as ran basis since we would never have the identical set up change duplicated and thus all would have to be observed.

PRESIDENT'S MESSAGE

By Gordon B. Carson

President, American Institute of Industrial Engineers, Inc.

Unceasing Education

He was obviously a man of circumstance and accomplishment. In fact he had forgotten more than some of the shiny-faced Industrial Engineers knew. But he was disturbed. "I can't read the new hieroglyphics," he said . . . "I don't understand the rash of sciences which the new look is putting out . . . and yet I know that if I could

understand the language, I could contribute to the general progress in Industrial Engineering."

This is typical of the position in which many mature engineers find themselves . . . regardless of specialty. But in Industrial Engineering progress has been much more rapid in the past few years than in some of the other branches.

Check your real positive knowledge. What do the following terms mean to you?

Decision Theory
Information Theory
Mathematical Statistics
Linear Programming
Operations Research
Systems Engineering
Standard Deviation
Variance
Servo Theory
Feedback
Closed Loop
Analog Computer
Simulation
Digital Computer

Most of you recognize the terms, of course, but the chances are that if you completed your formal education more than five years ago, your knowledge of the terms is sketchy or rudimentary in most cases.

Both the national organization and the local chapters have obligations to run short courses and refresher courses for the mature Industrial Engineers of each major chapter center. Not all programs can be alike, since local needs vary. But in every instance much can be taught and assimilated through mutual study and learning.

Let's examine our needs and start our own "Operation Bootstrap." There is *no* need for an alert Industrial Engineer to become obsolete. There is never a barrier to learning through age alone. Eagerness to learn is not the peculiar property of the very young.

So often we hear the term, "why don't *they* do something about it?" In this case "*they*" is you and me and all of our members.

By tackling the problem of continuing education for all those of our membership who want to participate, we can raise the level of attainment of the entire profession . . . and increase each member's ability to make personal progress and to improve his professional standing.

To start such a program is not easy. To run it will require the diligent and farsighted leadership of many. And it is one area in which all who participate can benefit many fold.

Invest in yourself . . . and in your profession. It is the only investment you will ever make over which you will have substantial and directing control!

A New Epoch for AIIE

At the August 21 meeting, the Board of Trustees voted to move our National Headquarters to New York when the new United Engineering Trustees Building is ready for occupancy in late 1960 or early 1961.

This new building, scheduled for erection at First Avenue between 46th and 47th Streets, will be across First Avenue from the United Nations area. It will be the national headquarters for all of the major engineering societies, and for such inter-disciplinary groups as the Engineers' Joint Council, of which AIIE is a member.

The Board made no hasty decision. In spite of the fact that AIIE has a heavy concentration of membership in the Midwest, and in spite of the personal bias favoring the Midwest on the part of many Board members, there could be only one conclusion: The future growth, power, and service of AIIE to its members demanded location in conjunction with the other top engineering societies.

In the interim period between now and 1961, headquarters will remain in Columbus, Ohio, where additional space has been engaged to fill the needs of our rapidly growing society. The present headquarters occupy a suite of rooms on the sixth floor of the Brunson Building, 145 North High Street.

Don A. Trenwith manages the office as Business Administrator, and in February, veteran member Floyd A. Titler will assume full-time duties as the first professional Executive Secretary of AIIE.

Better service to AIIE members is the objective of National Headquarters. And after 1960, it is hoped that a new position of ever-increasing influence in national affairs will be achieved by your society.

Progress is trouble. Growth may mean departing from practices of the past. But our society will always remain the champion of professional progress for Industrial Engineers, and will represent our segment of engineering in the councils of all engineering organizations.

You will be increasingly proud of your society, as it moves ahead in its national influence, and as it achieves for you a new position of respect in our ever-changing national economy.

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INSTITUTE INTERESTS

CALENDAR

November 14-15, 1957: Twelfth National Meeting of the Operations Research Society of America; Penn-Sheraton Hotel, Pittsburgh, Pennsylvania.

November 18-22, 1957: Second Annual University of Dayton Paperwork Simplification Conference; University of Dayton, Dayton, Ohio. Write University of Dayton Public Relations Office, 300 College Park Avenue, Dayton 9, Ohio.

January 6, 7 and 8, 1958: Fourth National Symposium on Reliability and Quality Control; Hotel Statler, Washington, D.C. Write Richard M. Jacobs, RCA Bldg. 108-2, Moorestown, New Jersey.

January 27-February 6, 1958: Engineering and Management Course; University of California, Los Angeles. Write Administrative Staff, Engineering and Management Program, U. C. L. A.

March 17-21, 1958: Fourth Nuclear Engineering and Science Conference; Chicago, Illinois. Write Atomic Exposition, 117 South 17th Street, Philadelphia 3, Pennsylvania.

PERSONALITIES

David B. Porter

Nineteen members of New York University's faculty and administrative staff retired this summer. They include the University controller, one dean, an assistant dean, and four chairmen of academic departments. Nine full professors, all of whom have assumed the title of professor emeritus in their respective fields, also retired. One of these was David B. Porter, in the College of Engineering, who was named a Fellow in the American Institute of Industrial Engineers in 1957.

Dickey Dyer

Dickey Dyer, a veteran of 16 years experience in Industrial Engineering and management consulting, has joined George Fry & Associates, the Chicago-New York-Los Angeles management consulting firm, and has been appointed resident manager of the firm's New York office, it was announced by William J. Biehl, president.

Formerly a member of the consulting firm of Welling & Woodward in New York, specializing in new products engineering, Dyer from 1951 to 1955 was business manager of the Work-Factor Company in Cleveland. From 1941 he was associated for ten years with Dyer Engineers, Inc. in Cleveland, concentrating on the development of industrial cost control systems.

A graduate of Harvard University, Dyer is a member of the Society for the Advancement of Management, having served as vice president of the Cleveland chapter. He is also a member of the AIIE, serving last year as conference program chairman of the Cleveland chapter.

MEMPHIS CHAPTER

The July meeting was held on July 24 at the Union Planters Bank, Highland Heights Branch. The speaker for the evening was Mr. Hancel Bonds, one of our own Associate Members. Mr. Bonds is Supervisor of Industrial Engineering at Flexonics Corporation in Memphis. He earned his B.S. in Industrial Engineering from the University of Tennessee and his M.S. in Industrial Engineering from the University of Houston in Texas. Mr. Bonds spoke on a paper he presented to earn his Masters Degree; its title is "An Investigation of Industrial Engineering Functions and Personnel." This paper was the result of a survey of 1000 companies to determine the functions which Industrial Engineers perform in Industry, and to evaluate the Industrial Engineer as an individual as seen in the eyes of Industry.

Our August meeting was in the form of a dinner and dance held at the Mallory Officers Club. Families of members were invited guests. As an extra added attraction, our own Jimmie Barr presented a short humorous talk entitled "Analyze Your Home, or, An Industrial Engineering Approach to Housekeeping."

In September we met at Union Planters Bank for a most important session—the annual election of officers. After the election, a short film on Industrial Engineering was shown.

MIDDLE TENNESSEE CHAPTER

William Prather, senior plant Industrial Engineer for General Shoe Co., was elected president of the Middle Tennessee Chapter, AIIE, at the July meeting. He succeeds the chapter's first president, Wendell B. Graddy, of Tullahoma.

Other officers are Ernest Teasley, Manchester, vice president; Robert Koger, Tullahoma, secretary; and Harry Ginn, Tullahoma, treasurer. Named to the board of directors were: Mr. Graddy as membership chairman; Tom Bigger, Tullahoma, program chairman; Orrin J. Greenwood, Tullahoma, publicity chairman; and Lee Cushman, Tullahoma, constitution chairman.

This dinner meeting, held at the Tullahoma Golf and Country Club, opened with a social hour and closed with the showing of two films by Mr. Greenwood, one on motion study by the State University of Iowa and the other on conference leadership prepared by General Electric Co.

New Officers of Middle Tennessee Chapter: Front Row, left to right: Ernest Teasley, Vice President; William Prather, President; Robert Koger, Secretary. Back Row, left to right: Thomas Bigger, Program Chairman; Harry Ginn, Treasurer; Orrin Greenwood, Publicity Chairman; Wendell Graddy, Membership Chairman.

ROCHESTER CHAPTER

The Rochester Chapter, AIIE, held its Annual Spring Conference on Saturday, March 30, at the Rochester Chamber of Commerce. Titled "Management Science in Action", the conference was devoted to exploring the application of new scientific approaches to management problems.

Dr. Melvin E. Salveson, Operations Research Consultant for the General Electric Company, gave the luncheon address entitled "Looking Ahead in Industrial Engineering". He emphasized our increasing responsibility to "design progress". "Task forces of researchers are beating the bushes for new ideas, new concepts", he said "we must leave people free to do the unexpected. It is this concept on which progress is based."

"As the changes in Industrial Engineering become more complex," he said we "must focus our attention on the whole range of business activities. You can't change one part of the business without changing all other parts. . . . . they are all interrelated."

Highlighting the discussions was a talk by Dr. Charles I. Miller, Staff Physician for the Eastman Kodak Company, entitled "The Effect of Physiological Stress in Industrial Workers." He examined the increasing need for cooperation between the Medical profession and Industrial Engineers as a result of studies carried out nationally in the past several years to relate more directly working paces and heart rates. These studies have shown direct correlation of amount of energy expended on a job and heart or pulse rate. Close examination of the results show that length and frequency of rest periods have varying effects on output, dependent on the work load, nature of the work, and physiological make up of the individuals concerned. Dr. Miller conceded that work done, thus far, in this field is hardly out of the laboratory stages. However, it was emphasized that much is to be gained by continuing this type of research. Its potential impact can hardly be evaluated, but the progress made to date has been very significant. It is certainly an area that should bear more investigation by Industrial Engineers.

Robert B. Murray, of the general comptrollers office, Eastman Kodak Company, discussed the "Financial Aspects of Capital Equipment Justification." He explored various methods of calculating rates of return on investments and ways in which these rates can be used in capital budgeting problems.

Dr. Robert E. McGarrah, Cornell University, discussed the problem of employment and inventory levels in a talk on "Production Programming." A demonstration of a linear programming approach to cost minimization for this type of problem was given.

Rochester Spring Conference. Left to right: Dr. Charles I. Miller, Eastman Kodak Medical Dept.; Mr. William L. Diehl, Eastman Kodak Industrial Engineer, Chairman of the Conference; Dr. Melvin E. Salveson, Operations Research Consultant for the General Electric Company.

James A. Richardson, Industrial Engineer, Eastman Kodak Company, demonstrated various approaches to the measurement of Indirect Labor Operations. Robert W. Peacor and Melvin R. Witmer, also Industrial Engineers, Eastman Kodak Company, discussed several man-machine Productivity Relationships. They demonstrated various solutions using basic algebra, probability and Monte Carlo techniques.

The success of the conference was excellent. A total of 163 paid attendants was recorded. Of these there were 12 from chapters outside of Rochester and 121 non-members. Twenty-eight companies from upstate New York were represented.

BOARD OF TRUSTEES' MEETING

National Headquarters

Columbus, Ohio

August 24, 1957

The Board of Trustees of AIIE is the official governing body of your organization. This group meets to conduct business for you twice a year. The official minutes of the August Board of Trustees' meeting are published in the Journal to keep you informed of AIIE activity.

President Carson called the meeting to order at 9:00 A. M. Among those in attendance were:

Members of the Board of Trustees:
Gordon B. Carson, President
Floyd J. Titler, First Vice President
Ralph W. Updegraff, Treasurer
Frank F. Groseclose, Board Member-at-Large
Howard P. Emerson, Past President
Edwin L. Slagle, Past President
Harold T. Amrine, Central Region Vice President
Harry Davis, Northeastern Region Vice President
Warren Alberts, Board Member-at-Large

Special Task Committee:
Matthew A. Payne, Chairman

Business Administrator:
Don A. Trenwith

1. *The Minutes* of the May 17, 1957, Board of Trustees were approved as presented.

OLD BUSINESS

2a. *Participation in United Engineering Trustees Building, New York City*—The Board of Trustees was brought up-to-date on the proposed move by the report of Matthew A. Payne, Chairman of the Special Task Committee and Gordon B. Carson, President. After a considerable discussion of the pros and cons of such a move, the Board took the following action:

Mr. Slagle moved that the President of the AIIE contact the building coordinator of the United Engineering Trustees Committee and advise him that the AIIE would like to occupy space in the new United Engineering Center; and that the Board of Trustees take immediate action to request the Internal Revenue Department to change the AIIE tax exemption status from 501 c 6 to 501 c 3. Motion seconded by Warren Alberts. Motion carried with one dissenting vote.

2b. *Rotary Fund*—No action was taken during this meeting because of the lack of complete information as requested of the Research Committee.

2c. *Other Old Business*

2c1. *Journal Printing Costs*—Various Board members discussed their findings in inquiring into the cost of printing the AIIE *Journal*. The consensus of opinion was that the price charged by our present printer is well within line considering the quality of the work and particularly their excellent handling of formulae and other technical data.

2c2. *Recognition of Industrial Engineers who have become Deans of Engineering Colleges*—Colonel Groseclose moved that the name

of Dean H. A. Fisher, Dean of Engineering at Washington University, St. Louis, Missouri, be added to those recognized by the Board at the May 17th meeting. Seconded by Professor Emerson. Motion passed.

NEW BUSINESS

3a. *Membership Report*—The Membership Reports of August 1, 1957, were reviewed by the Board. Colonel Groseclose moved that the Membership Reports of August 1 be approved as presented. Mr. Amrine seconded the motion. Motion carried.

3b. *Financial Report*—Colonel Groseclose moved that the Financial Report be accepted as presented by the Treasurer. Seconded by Mr. Titler. Motion carried.

3b1. *Application Fee Change*—After considerable discussion, the Board wished to call the attention of the membership to the fact that future dues increases might not be required if the application fee was increased to be more in line with the fee charged by other societies. No action was taken to change the fee at this time.

3c. *1957–58 Budget*—The Budget as presented by the Treasurer, was reviewed by the Board with one change as shown below. The budget was approved for the fiscal year October 1, 1957 to September 30, 1958. The change:

Mr. Slagle moved that $5,000 of the 1956–57 operating surplus and $5,000 from the 1957–58 budget be established as contingency reserve to meet the cost of the proposed move to New York City. Seconded by Mr. Titler. Motion carried.

The Board directed the Treasurer, the Secretary and the Business Administrator to make the necessary changes in the approved 1957–58 budget to achieve the results directed in the above motion.

3d. *Proposed Chapter Development Program*—Mr. Alberts moved that the Chapter Development Program be approved in principle with the suggestion that the National Director of Programs and his staff may wish to simplify the operation and grading system to be used. Seconded by Mr. Amrine. Motion carried.

3e. *Other New Business*

3e1. *Request for Chapter Dues Advance*—The Board reviewed the request from an organizing chapter group and approved their request for a $50 advance to meet organizing expenses. Seconded by Professor Emerson. Motion carried.

3e2. *Adjournment*—At 12:45, Colonel Groseclose moved the Board Meeting be adjourned. Seconded by Mr. Slagle. Motion carried.

Note—Next Executive Committee Meeting, September 28, 1957, to be held at National Headquarters.

READER COMMENTS

Apropos of Dean Sweigert's article on page 189 of the May-June Journal and of other recent articles in the professional press I thought you might find the enclosed article thought provocative and of very definite reader interest. If so, you are at full liberty to publish it either in Reader Comments or in such other form as may best serve the purposes of the Journal and/or the profession of Engineering.

It was prepared as an answering challenge to the raucous clamor for all engineers to fall in line and join unions. It is an attempt to put in words the reasons for the misgivings and hesitancy of many of our best engineers to be so regimented. To the extent that it may help engineers to clarify the fundamental reasoning that should prevail in a profound issue of this type it will have served its purpose very well.

Some industrialists have told me it is an indictment of the present industrial system while some union officers have told me that I misjudge the philosophy of present day unionism. As no one has ventured to call me a communist for having thus expressed my thoughts I can't help but feel that perhaps I have hit upon a sound middle ground upon which we, as a truly professional group, may take a firm stand.

Whether or not you see fit to print the article I shall be deeply appreciative of your comments on it.

THE PROFESSIONAL PROBLEM IN INDUSTRIAL RELATIONS

Question: When is a union not a union?

Answer: When its members are truly professional people.

Question: Why can't professional people join a union?

Answer: They can join one, but not in legitimate anticipation of the normal fruits of unionism. They cannot seek seniority, compulsion, tenure, uniform wages, or uniform benefits for all the union members.

Question: Why can't they legitimately seek seniority, for example, through a union?

Answer: Because, if they were granted, and lived under, a normal seniority system they would no longer be professional people! Under normal conditions a professional man knows that his advancement is, and should be, based strictly on his creativity and useful productivity. He knows that based on these alone he should be hired, fired, retained, promoted, or demoted.

When a union and an employer bargain collectively each must give up something to the other to gain something it wants for itself. The union obtains seniority, for example, while an employer obtains an agreement not to strike the plant. Or the union obtains a fringe benefit while the company obtains a reduction in the amount of hourly wages it might otherwise have had to pay. Such is the very nature of union bargaining.

But why can't the professional man better himself this way too? He can't, because if his value to the employer lies in his being a truly professional man (not merely a highly trained technician), then he has nothing with which to bargain! He cannot say, for example, "I will give up or shade my ethics for a fancy seniority plan," or, "I

will give up my right to publish newly discovered scientific truths in exchange for a wage increase or a pension plan." Neither can he say, "I will give up my right to conscientiously practice my profession and instead do the strict bidding of my superiors in exchange for a promotion or fringe benefit". He cannot do this because the moment he gives these things up through individual or collective bargaining he is no longer a professional man in the eyes of his peers. A professional man has only his reputation, his talents, and his integrity with which to make his professional progress and income. He cannot delegate these away to a union agent to put on the bargaining table for him. He is unlike the laborer who can truly delegate or assign his vote to perform any fitting task for any employer willing and able to pay agreeable wages.

Perhaps a true case from industry will illustrate the problem of the professional man and his employment status.

My client, the company, had engaged a doctor to give preemployment physicals to otherwise acceptable applicants. The examination was to be routine and not of an exhaustive nature that would permit the detection of certain uncommon social diseases. However, the doctor was told that it was strictly company policy never to employ a person with any of certain disabilities or specified social diseases. The doctor practiced half time at the plant and half time at his own office. One day the doctor was asked to pass on the physical acceptability of an applicant that had for the past year been under private treatment by this same doctor for a social disease. The company examination did not cover the particular condition but the applicant merely had checked "NO" on the medical questionnaire form that inquired about the disease.

There was a practical professional ethics question as to whether the doctor's duty lay first to the employer, to the patient, or perhaps to his profession. There was not much question but that other doctor's patients under similar conditions had secured employment with the company. What should he do? He confided the problem to me as a professional consultant to the company on its industrial relations activities. As the doctor was under a definite dollar contract with the company, the company felt it could and should dictate the policies it wanted carried out. I recommended, and the company and the doctor agreed, that the contract be torn up and that a truly professional relationship be established whereby the doctor was given a free hand and both the company and the doctor could immediately sever connections if either became dissatisfied. In this way the company obtained true professional services that could be retained or stopped at will. The doctor kept his professional status as he no longer had to work under rigid company policies but sold his good services for as long as they were wanted.

This illustration, while lengthy, is necessary to point out the peculiar status of the truly professional man. He works under the rules and laws of nature and of his professional organizations. He must always be in a position to abide by them regardless of what a particular employer may want or direct him to do. It illustrates why many first class musicians and teachers, among others, no longer have true professional status since they play, teach, perform, or act only what others tell them they may or must. They do not have the liberty of selection or movement that characterizes the professional person. And as long as they are willing to give this up for security, tenure, uniform wages, etc., they have automatically withdrawn themselves from the professional class and status. Many will say, I am sure, that since they can't be both, they have made the wiser choice of being good union people rather than good professional people. At least, many seem happier this way and I have no fight with their choice.

We started by asking the question: When is a union not a union? And it was answered: When its members are truly professional people. We now close by asking: When is a professional man not a professional man? And it is answered: When he gave up this status by banding together to bargain for the normal objectives of unionism. — *Elmer C. Hughes, Industrial Consultant, Syracuse, New York.*

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RECENT READABLES

AUTOMATION

"Electronic Data Processing Machines," by D. H. Ware, W. J. Martiny and F. J. Maginnes, *Mechanical Engineering*, page 632, July 1957.

Electronic data processing machines are applicable to nearly all engineering activities, resulting in more efficient engineering operations, and more effective management control. They broaden the base for decisions, speed up research and development studies, and force standardization of procedures as well as products. The gains from an integrated data processing system are sizable, but the problem of selecting the equipment, and recruiting and training the operating staff also are sizable. On a large project, several years may be required to regain the starting costs out of the savings from using the system.

In addition to the many applications in accounting and business, electronic data-processing machines, EDPM, are offering new opportunities in all activities of engineering from research and development studies, major design planning, production engineering design calculations, on through the documentations of engineering information leading up to the generation of manufacturing instructions.

"The Automatic Pipeline," by M. T. Nigh, *The Oil and Gas Journal*, page 89, July 8, 1954.

The automatic pipeline has been in the making for 30 years, ever since the first unattended pump station was built. Automation in one form or another is being relied on increasingly to handle a growing job of transporting petroleum and natural gas economically and efficiently. The automatic pipeline has been put together little at a time, and now the whole is complete save for one final part. Remote-controlled stations have become commonplace. The next chasm to be bridged is from remote control to a completely self-controlled system. This will mean turning over the chief dispatcher's decisions to a computer, which up to now has done almost everything with a pipeline but run it.

"New Digital Computer is Especially Designed for Process Control," by D. H. Stormont, *The Oil and Gas Journal*, page 151, September 2, 1957.

A great step toward the much-discussed "push-button" refinery will take place next year. A new digital control computer, specifically designed for automatic control of refinery and petrochemical processes, is scheduled to be incorporated into the control setup of a refinery process.

When used as a central unit of a process control system, the new computer can automatically read process instruments, perform the computations necessary to relate these readings to process objectives, determine the control actions which will result in optimum plant operations, and activate the process mechanisms or adjust set points on supervised control loops to bring about the desired operations.

GENERAL

"Preparation and Evaluation of an Industrial Report," by C. L. Tutt, Jr., *General Motors Engineering Journal*, page 30, September 1957.

Industrial reports assist management in making policy and operating decisions by presenting factual information about current or future operating and product design problems. Because of their importance it is essential that such reports be prepared in a uniform manner and be complete, concise, and accurate. Since 1945 General Motors Institute has supervised the preparation of over 2,000 industrial reports required as part of the Fifth-Year program leading to a Baccalaureate degree in either engineering or business administration. Experience gained with the wide range of material covered in these reports has lead to the development of specifications which maintain organizational uniformity in their preparation and final make-up. A set of guiding questions also has been developed which serves to evaluate the report as to its technical content and logical presentation of this content.

"How to Build Good Communications," by Editors, *Iron Age*, page 33, August 29, 1957.

Management has come to recognize that many of its bad decisions are the result of poor internal communications. Some companies are actively trying to see that they are not the victims of faulty means of keeping all levels of the company informed. This means not just management, but workers as well. This survey of hundreds of metalworking plants shows management's growing awareness of this fact and what it is doing to improve its lines of communication.

"Planning Product Strategy," by P. R. Maruin, *Machine Design*, page 110, June 13, 1957.

Planning product strategy is undoubtedly the most taxing and harassing problem confronting a company. At the same time it is one of the most challenging opportunities. The horizons are relatively unlimited. The planners must take all of the available facts and, anticipate probable patterns of industrial and consumer activity in years ahead, set programs in motion designed to fit into these new patterns. This article considers the overall aspects of product planning; subsequent articles in this engineering-management program will explore five essential phases:

1. Finding New-Product Ideas
2. Screening and Appraising Ideas
3. Testing and Evaluating Proposals
4. Commercial Development of Products
5. Preplanning for Production

MATERIALS HANDLING

"Computers Control Warehouse System," by Editors, *Modern Materials Handling*, page 150, June 1957.

A completely new concept of automated warehousing based on an over-all "system" approach means faster service, lower costs, and fewer errors in warehousing operations. Highlights of the overall warehouse system include:

1. Automatic controls for directing order-accumulation operations.
2. A case sealer that adjusts automatically to five different sizes of shipping container.
3. An automatic tally that spots human errors in routing before shipments are made.

4. Controls for sorting outgoing shipments.

5. An automatic set-up that stacks cartons six high on accumulation lines on the shipping dock. This saves dock space.

6. A mechanized system for paperwork that eliminates delays from this source.

7. Provision for expansion within the present building and the present system.

"How Operations Research Aids Materials Handling," by I. Heftner, *Modern Materials Handling*, page 107, August 1957.

While many definitions have been proposed, actually operations research is nothing more than the application of scientific method to industrial problems. In materials handling, it can be applied to attain the following objectives:

1. Determining plant and warehouse locations for minimum distribution costs and maximum profits with linear programming methods. Optimum utilization of machine capacity (including powered materials handling equipment) is another use to which linear programming may be put.

2. Determining personnel requirements for storerooms to assure smoothest operation with minimum clerical idle time and customer waiting.

3. Maintaining inventory at minimum levels while assuring optimum service to customer.

"The Push-Button Warehouse," *Fortune*, December 1956.

Automated production lines have been turning out goods faster than antiquated warehouses can handle them, and to break the jam Industrial Engineers are now applying the automation principle to the warehouses themselves. Describing how a number of companies are speeding up their warehouse procedures with computer-controlled conveyors and other automatic devices, the author concludes that, despite the necessary changes in packing methods and the high cost of the equipment, push-button warehouses will bring substantial long-range savings.

"Simplified Storekeeping for Smaller Organizations," by Stanley H. Mansbridge, *Office Management*, January 1957.

For the small company that cannot afford expensive electronic methods in storekeeping and inventory control the author outlines alternative procedures for simplifying and improving these functions. He describes some forms to facilitate accurate record-keeping and suggests that continuous stock-taking can eliminate the dislocation caused by a once-a-year inventory check.

"How to Plan Receiving Operations—Part I," by H. G. Weiss, *Modern Materials Handling*, page 123, September 1957.

This is the first part of a comprehensive report on how to obtain an efficient receiving operation. Top management, focusing more and more attention on this area, now recognizes it as a gateway of opportunity for cost reduction often overlooked in the past.

Based on text material from General Electric Company's Receiving Operations Workshops, here are proven methods to help you analyze your own operation, make improvements and measure performance. This article proposes several ways of providing a faster, more accurate and economical receiving service.

"New Tool for Automatic Handling," by L. L. Bosch, *Modern Materials Handling*, page 107, September 1957.

Describes how the new techniques of static control, previously used almost exclusively with automatic machine tools, perform a precise materials handling operation. The system is a complex warehouse in which cartons from 11 production lines converge to a single line for dispatching to any of 72 storage lines.

A high degree of precision is necessary in the operation. The accuracy and dependability of the static control circuit has made this possible.

This system consists of four major parts:

1. Transport and merging system, which conveys cartons from the respective production areas and merges the flow onto a single line leading to the jib crane conveyor, or dispatch point.

2. Jib crane conveyor, which identifies the cartons by reference to a memory source and delivers them automatically to any of 72 "on conveyor" storage lines.

3. Magazine storage, which consists of some 11,000 ft. of gravity roller conveyor. These are arranged in three groups of three conveyors wide and seven, eight and nine conveyors high, respectively.

4. Conveying system from storage to shipping docks, which is an intricate arrangement of fixed and swing-powered conveyor sections and gravity lines for selectively conveying cartons from 69 of the 72 storage lines to the four loading dock areas.

QUALITY CONTROL

"Statistical Toleranceing," by R. L. Thoen, *Machine Design*, page 121, June 13, 1957.

Tradition and human inertia have been largely responsible for the widespread neglect accorded the matter of product tolerances. As a consequence many drawing specifications are incomplete, redundant, meaningless and unnecessarily close. Likewise, product parts are made and inspected according to so-called "practical" interpretations of these unrealistic specifications.

To avoid this dilemma, it is necessary to specify product tolerances that are just as liberal as assembly functional requirements will permit. For interchangeable manufacture, this criterion means tolerances based on probable rather than additive combinations. Designers should be familiar with those parts of probability theory that have to do with how tolerances combine.

WORK MEASUREMENT

"Leveling Peak Office Workloads," by D. A. Stivers, *Modern Office Procedures*, page 3, February 1957.

One of the most serious problems affecting normal office operation is frequent fluctuation of the workload level. One company's solution has made it possible for clerical personnel to handle peak loads without disturbing the normal routine. The solution was a work measurement program and the appli tion of its findings in two ways: 1. a forecast of personnel assignments according to departmental work loads; 2. the creation of an exchange group which makes it possible to trade personnel among departments when the workloads fluctuate.

BOOKS

Appraising the Economics of Electronic Computers, by Frank Wallace, Controllership Foundation, Inc., 2 Park Ave., New York 16, N. Y., 1956, 106 pages, $4.00.

A systematic inventory of the procedures to be followed in determining office equipment requirements, estimating the cost of computer installations, selecting and training electronics personnel, and scheduling computer operations. Appendices include a review of the basic concepts of computers, a listing of computers commercially available, and a brief explanation of Operations Research.

Automation in Business and Industry, edited by Eugene M. Grabbe, published by John Wiley & Sons, Inc. 1957, New York, N. Y., 611 pages, $10.00, Cloth bound.

The fundamentals of automation, new developments in

automation, techniques, and descriptions of automation systems are included in the wealth of information supplied by this new work.

Based on a series of lectures given by a number of engineers and scientists at the University of California, the book shows how the fields of feedback control theory, instrumentation, analog and digital computation, and data processing are now becoming integrated as automation is applied on a broad scale to control systems.

Operations Research, Special Report No. 17, American Management Assoc., New York, N. Y., $3.75 (AMA mbrs. $2.50), paper bound.

Operations research, for many executives, is surrounded by a fog of unfamiliar language and mathematical formulas that will be dispelled only when the techniques used and the resulting benefits are explained clearly and simply in nontechnical terms. This AMA report does a commendable job of fog-dispelling.

After a general review of operations research and its background, company executives outline particular phases of their work in which they are using OR successfully. The problems are stated in standard business terms, and the processes by which they were found and isolated are traced in detail. Then follows a complete description of how the necessary data were developed, what specific OR approach was applied, and in many cases, how the answer to one problem led to the discovery and solution of others.

Quality Control for Plastics Engineers, edited by Lawrence M. Delang, Reinhold Publishing Corp., New York, 1957, 142 pages, $4.95.

Using the theme "quality cannot be inspected into a product; it must be built in," the ten papers presented in this volume attempt to show that the more adequately plastics manufacturing processes are controlled, the less is the likelihood of scrap and rejects in making plastics parts. Authored by experts in the field of statistical quality control, the papers cite examples of statistical quality control techniques currently used in the industry.

Standard Costs: How They Serve Modern Management, by Clinton W. Bennett, Prentice-Hall, Inc., Englewood Cliffs, N. J., 535 pages, $10.65.

Describes standard cost procedures, as used by many industrial companies, to include not only accounting but management and engineering as well. Management determines the program; engineering develops the methods, procedures and standards; accounting applies money values, provides controls and compares results. The author follows the consultant approach and the case method of illustrating procedures.

Statistical Methods in Quality Control, Dudley J. Cowden, Prentice-Hall, Inc., New York, N. Y., 1957, 751 pages, $12 cloth.

The first 12 chapters of this book are concerned mainly with statistical methods in quality control. Others chapters deal with process and product control, elementary principles of probability, binomial and multinomial distributions, use of control charts, analysis of defectives, principles of lot acceptance sampling for attributes, and double sampling.

Although mathematical derivations of some formulas are given, nothing has been included that is mathematically difficult. The more tedious mathematical proofs are given in appendices at the ends of chapters.

Successful Office Automation, by Ralph W. Fairbanks, Prentice-Hall, Inc., Englewood Cliffs, N. J., 1956, 355 pages, $10.00.

The author has directed his presentation to the business man faced with the problem of systems revision and improvement of office activities. His explanation of the systems approach and various levels of office automation is excellent.

Engineering Manpower—How to Improve Its Productivity, by George A. Von Peterffy, et al., Graduate School of Business Administration, Harvard University, Boston, 1957, 162 pages, $18.50.

An analysis of how industry is utilizing and motivating its engineers, this report is aimed at showing managers and administrators how and where engineering productivity can be increased. It is based upon a rather extensive survey and evaluation of industrial philosophy, policies and practices affecting engineers.

Motion Economy and Work Measurement, by Robert Lee Morrow, The Ronald Press Co., New York, 1957, 468 pages, $7.50.

A revision of Time Study and Motion Economy published in 1946. New material includes application of motion economy to office work, micromotion study, uses of photography for work analysis, and organization for methods improvement.

Practical Automation: Methods for Increasing Plant Productivity, by Lester R. Bittel, Morely G. Melden and Robert S. Rice, McGraw-Hill Book Company, New York, 1957, 384 pages, $7.50. (This book can be ordered from *The Journal of Industrial Engineering*.)

The authors, associate editors of *Factory Management and Maintenance*, have drawn freely upon their exposures to various phases of automation and have presented a practical guide to show how automation has been and can be used in manufacturing plants to increase productivity, cut operating costs and improve safety and working conditions.

Wage Incentives As A Managerial Tool, by William B. Wolf, Columbia University Press, New York, 1957, 143 pages, $3.50.

A study of wage incentive practices and experiences in manufacturing plants.

The author undertook his study of wage incentives to reconcile the conflicts between claims for beneficial results and actual results achieved by wage incentive installations. This report should receive serious consideration from all individuals interested in incentives of any form.

Statistics for Management, by B. J. Mandel, Dangary Publishing Company, Baltimore, 1956, 408 pages, $6.00.

"A simplified introduction to statistics," directed to the nontechnical individual. Well presented and generously illustrated with interesting examples.

Location & Space Economy, by Walter Isard, The Technology Press and John Wiley & Sons, Inc., New York, 1956, 350 pages, $8.75.

The basic objective of this book is to improve the spatial and regional frameworks of the social science disciplines, particularly economics. The author's theory tries to unravel the dynamic interplay of social and economic forces not only as they determine plant location, but also as they influence industrial concentrations and the geographic spread of industry among the several regions and nations of the world.

Office Automation—Integated and Electronic Data Processing, by R. Hunt Brown, Automation Consultants, Inc., New York, 1956, 300 + pages, $25.00.

An overall presentation of data processing, discussing almost all aspects of EDP & IDP, including various available equipment. An updating service is available to insure coverage of new developments.

I. E. OPPORTUNITIES

WHAT IT IS

The industrial engineering opportunities service is a functional committee of the American Institute of Industrial Engineers which collects information concerning employment opportunities on a nationwide basis and provides this information to members upon request. The committee is composed of members from the Columbus, Ohio chapter and the information is furnished free as a service to industry and Industrial Engineers.

SERVICE PROVIDED

Some of the known job openings will be published in condensed form in each issue of the Journal of Industrial Engineering which is issued bi-monthly to over 6,000 members and student members of the AIIE.

In addition, a monthly I. E. Opportunities Bulletin is supplied to over seventy chapters located throughout the United States.

Each job opening is assigned a "P" number for identification. The name and address of the person to contact for additional information concerning a specific job opening is sent to members on request.

ADDRESS OF THE SERVICE

I. E. Opportunities Service
American Institute of Industrial Engineers
145 North High Street
Columbus 15, Ohio

EMPLOYERS

Employers having openings for qualified Industrial Engineers are invited to list them with the Industrial Engineering Opportunities Service. Government agencies and educational institutions as well as business and industry are urged to take advantage of this free service. By publicizing your job openings with our Institute, you are sure of reaching high calibre men who have passed the Institute's strict membership qualifications and are fully qualified to fill many types of Industrial Engineering jobs.

Industrial Engineers are often employed in such fields as Work Measurement, Production Control, Plant Engineering, Operations Research, Industrial Relations, Sales, and Management. For a more complete coverage, see the following list of job classifications. Please do not hesitate to forward information on jobs in any area where it is recognized that an Industrial Engineering background will be of value.

To list your job openings with the Opportunities Service, send all or part of the following information with the name of your contact man to the above address: Type of industry, location, job classifications, minimum educational and experience qualifications, and salary range.

This information will be publicized to the members in condensed form in the Journal and in monthly chapter Bulletins. Company names are not shown. Should you desire a large ad elsewhere in the Journal advertising rates will be quoted upon request.

MEMBERS SEEKING JOB OPPORTUNITIES

The following list shows job openings available just before press time. If you would like more information about one or more of the positions listed, mail the "P" numbers with your name and address to the Opportunities Service at the above address. The Service will advise you by return mail of the name and address of the person to contact for further information, or advise you if the position is no longer available. Your name will not be forwarded to the company with the job opening so you must take the initiative yourself.

For more current listings, contact your local Chapter Secretary or Opportunities Chairman for the latest monthly Bulletin.

INDUSTRIAL ENGINEERING OPPORTUNITIES

Position number	Industry, location		Travel	Job classification number (See key)	Salary	Qualifications required			
					Range in $1,000	Adv. degree req'd	Years of exper.	Age range	
								from	to
19	Navy	Fla		30, 41, 42	6-1				
20	Electric, Mfg.	Mo							
21	Education	Mass							
22	Education	Cal		10					
23	Education	NY		10, 30, 40, 52					
24	Education	O		10, 20, 30, 42, 66	4-5 6-0				
25	Education	Wis							
26	Education	NC			4-2 4-8	M.S.			
27	Education	Puerto Rico		37, 53, 31					
28	Education	Va							
29	Garment Mfg.	Northeast		37, 31					
31	Paper Mill	Wis		11, 45, 80, 70, 32			1-5		30
32	Rubber Products	O		40					
34	Mgmt. Consult.	O	×	40			P.E.		
39	Education	Neb							
41	Mgmt. Consult.	O	×	10, 21, 31			5-7		

Position number	Industry location	Travel?	Job classification number (See key)	Salary Range in $1,000	Qualifications required: Adv. degree req.?	Years of exper.	Age range: from	to
42	Hospital O		10	4.8-7.2				
43	Airline Cal	×	11, 13	6-7.2				
45	Steel Products O		11, 13	4.8-5.4		0-2		
47	Chemical Proc. Conn		22, 23, 42, 43			3-8		
48	Chemical Proc. NY		22, 23					
49	Graphic Arts Ill		11, 20, 42, 43, 70			3-5	25	35
54	Hyd. Press Mfg. O		11, 13, 42	5.4-6.6				
58	Navy Pa		10					
65	Machine Tool Wis		11, 13					
67	Army Ordnance Pa			6.1-7.6				
68	Education Pa		10, 20, 31, 42					
69	Steel Products W Va		26					
70	Education NY		50		Ph.D.			
71	Mgmt. Consult. Ill	×	13, 21, 38, 42, 47, 70					
72	Airline Ill		70, 42, 43					
73	Consultant Pa	×	13, 21					
75	Army Ord. Ill		13, 31, 37, 70	7-9		2-4		
76	Trans. Panama		48	9.5-				
77	Post Office Minn		92-38, 40, 13	7.7-8.5		4		45
78	Mining & Smelt. NM		91-(10, 20, 30, 40)	8-11.1				45
79	Mining & Smelt. NM		10, 20, 30, 40			6-9.4		
81	Household Prod. O		70, 38, 50, 11	+ R		0-5		30
83	Textile Co. Ga		37, 42, 38	4.8-7.5				
84	Education NY		50 or 60	5.0-9.0				
86	Public Utility DC		13, 18, 37, 50, 52					
87	Linoleum Mfg. Pa		42, 26, 11, 53, 81			0-3		
89	Foundry Cal							
90	Education Fla							
91	Syn. Fibers & Films Pa, Va, W Va		10, 20, 42, 43, 72			0-5		
92	Paper Mill Pa		11, 13, 42			2-3		
93	Foundry Ill		11, 19, 30					
95	Airframe Mfg. Midwest		92-13, 19, 11, 40			5	30	40
96	Navy Md		40	7.5-8.6		3.5		
97	Railroad Md		54, 50, 11	8.4				
98	Timber Mill N West	×	91-30, 40				35	
99	Process NJ		92-30	12-15			35	45
100	Manufacturing Ill		95	15 + B			37	42
101	Air Force Ala		13	5.4		2		
103	Durable Goods NY		11, 13, 21, 42	5.2-6.0				
104	Rug Mill Pa		11, 13, 21, 42	6.0-7.0				
105	Electrical Mass		92 or 37 or 11	6.5-11.0				
106	Sugar ND, La, SC, Conn		13, 43			0		
107	Aircraft Wash		13, 30					
108	Mgmt. Consult Overseas	×	10, 20, 60				35	40
109	Paper NH			6.0-6.5				
110	Aircraft Tex		11, 13, 19, 70	5.4-6.6				
111	Chemical Ala			7.5				
112	Aircraft Tex		11, 40, 70					
113	Chemicals NJ		52					
114	Paper Mo		11					
115	Foundry, Educ. Pa							
116	Instruments NY		71	8.0				
117	Electrical Mass		50					
118	Mfg. Pa		11, or 16 or 37			4-8		
119	Paper Ga		10, 20, 30, 42					
120	Air Force Ga		I.E.	7.0				
121	Navy Cal		11, 13, 42, 43, 53	6.1-7.6		2-6		
122	Navy Va		I.E.				4	
123	Printing NY		49, 53			2-4		
124	Mineral Prod. NJ		11, 53			0-3		

INDUSTRIAL ENGINEERING OPPORTUNITIES—(*Continued*)

Position number	Industry, location		Travel?	Job classification number (See key)	Salary	Qualifications required		
					Range in $1,000	Adv. degree req.?	Years of exper.	Age range
								from / to
125	Chemical	Mich		13, 21, 43, 33			1-5	
126	Boilers-Fdry.	O		10, 20, 30, 42, 43, 44	7.2			25 / 35
127	Theatrical	NY		42, 43, 45, 49	10-12		5-	
128	Cartons	Conn			4.8-5.9		0-3	35
129	Education	ND		Asst. Prof. I.E.				
130	Heat Exchangers	NY		92-37	8.0-10.0			
131	Radiators	Md		44, 48	6.5-7.6			
132	Oil Seals	O		10, 20, 42, 45, 53	6.0		2-	25 / 30
133	Flour Mills	Minn	×	11, 13, 42, 43, 94	7.2-8.4			40
134	Education*	W Va		52, 53				40
135	Electrochemical	Midwest		92-80	15-20			
136	Hospital	Pa		11	6.0-8.0		2-	
137	Copper†	Chile, S A	×	31, 39, 43, 64	9.0			
138	Wax	Wisc		11, 19, 42, 47, 81	5.9-6.9		2-4	
139	Pharmaceuticals	Ind		11, 13, 21, 42, 44				
140	Magazine Editorial	Mass		43	5.0-7.0			
141	Steam Electric Power	Toronto		93-80	11.0		13 (P.E.)	35 / 45
142	Consumer Products	Midwest		95	15 + Bonus			25 / 40
143	Construction	NY		92-36, 38	11.0-14.0			32 / 45
144	Aircraft	Texas		15, 19, 39, 42, 44, 53	4.8-6.4		2-5	22 / 45
145	Lithography	Vt		31			2	
146	Air Force Depot	Ohio		I.E.	7.0-7.6			
147	Paper & Bag Mfr.	Ala		10, 20, 35, 43, 54, 70				
148	Steel Mill	Italy	×	30, 42	12			30 / 40
149	Agricultural Marketing	Wash, DC	×	10, 42, 43, 53	6.1		1-	
150	Aircraft Engines	NJ		11, 18, 38, 47, 70, 90			5-	
151	Medical Supplies	NJ		11, 21, 30, 42, 43, 50				
152	Electronics	Ky		10, 32, 39, 40	4.8-7.2		2-5	
153	Woodworking Tools	Texas						
154	Metal Furniture	Va		30, 36, 44			5-10	30 / 45
155	Electronics	Texas		11, 13			3-	
156	Plastics	Texas						
157	Aircraft	Colo		Mgmt. Engrs.			5-	

* Begins Sept.
† 3 yr contract.

AIIE OPPORTUNITIES SERVICE

Key to Job Classifications

No.	Job Classification	No.	Job Classification	No.	Job Classification	No.	Job Classification
10	Motion and Time Study	30	Production Engineering	45	Specif., Select. & Eval.	66	Safety Engineering
11	Methods Improvement	31	Production Control	46	Replacement	67	Suggestion Systems
12	Suggestion Systems	32	Process Planning and Routing	47	Automation	70	Systems and Procedures
13	Work Measurement and Perf. Stds.	33	Scheduling and Loading	48	Plant Maintenance	71	Admin. & Operating Procedures
14	Stop Watch Time Study	34	Flow Process Charting	49	Cap. Budget. Facil. Plan	72	Organization Charts and Manuals
15	Std. Time Data Dev. & Applic.	35	Inventory Control	50	Operations Research	73	Records Admin. & Form Control
16	Predeter. Elemental Time Stds.	36	Cost Anal. & Reduction	51	System & Simulation with "Models"	80	Product Design
18	Work Sampling	37	Statistical Quality Control	52	Mathematical Analysis	81	Packaging
19	Estimating and Costing	38	Budgetary Control, Standard Costs	53	Engr. Economy Studies	90	Management and Supervision
20	Wage Payment	39	Tool and Gage Design and Control	54	Auto. Data Proc. with Computers	91	Industrial Engineering Supr.
21	Incentive Plans	40	Plant Engineering	55	Market Research & Forecasting	92	Chief I. E. or Equiv.
22	For Production Workers	41	Plant Location & Expansion	60	Industrial Relations	93	Plant Engineer
23	For Non Prod. Workers	42	Plant Layout	61	Personnel Administration	94	Production Supervisor
24	For Supervisory Personnel	43	Material Handling	62	Personnel Testing	95	Plant Mgr., Fact. Mgr., Works Mgr.
26	Job Evaluation	44	Machinery & Equipment	63	Personnel Training	96	General Manager
28	Wage Administration			64	Industrial Psychology		
				65	Labor Relations		

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